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PUBLIC LIBRARIES AND INFORMATION SERVICES IN GREAT BRITAIN

A HUNDRED years ago, on August 14, 1850, the first Public Libraries Act received the Royal Assent, and English and Welsh town councils with a population exceeding ten thousand were empowered to levy a rate up to a halfpenny in the pound for the building or maintenance of a public library but not to spend any of it on books. This piece of legislation is sometimes known as the Ewart Act, in acknowledgment of the services of William Ewart, member for the Dumfries Burgh, who was chairman of the select committee of the House of Commons appointed on his motion in 1849 and whose recommendations led to the Act.

Although it was not the first Act on the Statute Book to deal with public libraries—an Act for the better preservation of parochial libraries in England was passed in 1708, and two county boroughs established libraries under the Museum Act of 1845—the Library Association is very fittingly celebrating the centenary of the 1850 Act as the start of a great social institution which has increasingly throughout the century been of incalculable benefit to the people; public libraries have set many on the road to achievement and hold possibilities which have probably not yet been envisaged, even in the survey of the public library system of Great Britain which Mr. L. R. McColvin made eight years ago. The provisions of the Act were extended to Scotland and Ireland in 1853; and in 1855 a further Act reduced the population limit for authorities or combinations of authorities to five thousand, raised the rate limit to a penny, at which it remained until the Act of 1919 removed any such limit, and permitted expenditure on books. The Act of 1919 gave county councils the power; but, in Scotland, burghs still suffer from the limitation of rate to threepence in the pound.

An admirable booklet* issued by the Library Association in connexion with the centenary well indicates the progress which has been made. There are now 587 library authorities, with stocks of forty-two million books, on which more than twelve million readers borrow to the extent of more than three hundred million volumes a year. To-day only sixty thousand people are in areas without library service, and expenditure has risen from £83,000 in 1878 to £3,177,960 in 1939 and £7,705,000 in 1949. The average expenditure per head of population last year was only 9½*d*. or 3*s*. 2*d*. per borrower. Many libraries already spend twice or thrice that amount or more and give a proportionately better service, while a study by the Library Association shows that at least two shillings per head of population should be expended annually.

All this growth was at first slow, and standards of service still vary considerably. Library services had already been initiated by local authorities in Warrington and Salford, while Liverpool had appointed a Public Libraries Committee before the Act of 1850.

* A Century of Public Libraries, 1850–1950. Pp. 28. (London: Library Association, 1950.) 6*d*.

Before the end of 1850, Brighton and Norwich had also become public library authorities; Bolton, Ipswich, Liverpool, Manchester and Oxford followed in 1852, and by 1860 there were twenty-eight, among which was London, represented by Westminster. Later progress was stimulated by the benefactions of Andrew Carnegie and J. Passmore Edwards and by the improvement in educational and social conditions. An important factor has undoubtedly been the work of the Library Association, founded in 1877 and incorporated by Royal Charter in 1898.

Although no other country in the world has achieved such high standards of coverage, the celebration of this centenary is no occasion for complacency. There are too many library services which are inadequate and ill-supported. Mr. McColvin's report left no doubt that, even eight years ago, good libraries were few, and gave an outstanding impression of the unsatisfactory general provision and of a badly organised system which stamps permissive legislation in this field as a comparative failure. Understaffing and inadequate premises, parsimonious expenditure on books and indeed every other item were still rife, and Mr. McColvin described reference library work as the outstanding failure of librarianship in Great Britain.

In its centenary booklet, the Library Association recognizes the necessity for a general raising of standards and that the present variations are a reproach to all. Progressive authorities are spending more than 5*s*. per head of population a year on the library service; but the Association believes that the first condition for good future development is that the provision of adequate services by library authorities should be made compulsory and no longer permissive. There should also be a government department, preferably the Ministry of Education, responsible for guiding, encouraging and co-ordinating the work of local authorities. All local authorities should be assisted financially to develop their library services.

Since the McColvin report appeared, there has been some outspoken comment on various aspects of the library service of Great Britain. The Library Association pamphlet itself recognizes that a good reference library is a necessity in any community. At the Aslib Conference in 1949, Dr. Percy Dunsheath spoke strongly about the inadequacy of present-day reference library facilities in science and technology. Reference library facilities in these subjects he considered were a disgrace to Great Britain, and even the Ministry of Education had not realized the educational value of a highly efficient library in the field of science and technology.

Dr. Dunsheath urged the establishment in the centre of London of a new library of science and technology conceived on the grand scale, using the practical experience and tradition of the Patent Office Library, and at least five times as large. Still more recently, in the second Henderson Memorial Lecture on March 31, dealing with the growth of applied chemistry in Glasgow, Dr. W. M. Cumming, in commenting that reference libraries, particularly in technology, are few and far between and largely out of date, urged the provision of first-class reference libraries of science and technology in all the large cities of Britain. There is no first-class reference library in technology in all Scotland, he asserted, and he suggested that the Department of Scientific and Industrial Research might sponsor some such scheme for disseminating knowledge to those who would use it if it were made readily available.

Dr. Dunsheath and Dr. Cumming were, moreover, speaking in line with the recommendation of the Royal Society Scientific Information Conference in 1948 which had urged the Government in the United Kingdom to give increased support to central scientific libraries and information services, in particular the Science Library and Patent Office Library. At the same time the Conference urged library committees to give more attention to co-operation between libraries with the object of reducing undesirable duplication and of extending access to a greater proportion of the world's literature. It was suggested that co-operation should commence in local areas, and that regional centres should be linked with national and international systems of interchange.

This is in line with Mr. McColvin's advocacy of the development of a nation-wide reference service by the adoption of a deliberate national policy of linking up and strengthening existing special libraries, of reducing unnecessary duplication, and of gradually extending their range. The proposals of the Council of the Library Association in September 1943 suggested that the establishment and maintenance of those departments of a national library service which can most efficiently be provided for the benefit of areas larger than those of library authorities, such as regional reference libraries, inter-library co-operation and the National Central Library, should be the responsibility of a department of the Central Government. Other possibilities of co-operation have been indicated in the reports of Mr. J. H. P. Pafford and of Dr. Marjorie Plant published last year.

Although little, if any, Government action is to be recorded during the past eight years, the Information Services Committee appointed by the Council of the Royal Society in July 1948 to follow up the recommendation of the Conference has been considering improvements in the national central scientific libraries. At the request of the Lord President of the Council, the Panel on Technical Information Services of the Committee on Industrial Productivity has made a survey of scientific and technical library facilities, though not in the detail which was suggested in the proposals formulated in 1946 for the post-war development of the university and research libraries of Great Britain by the University and Research Section of the Library Association

The survey fully justified the assertion that the development of technical library facilities has failed to keep pace with the growth of scientific research, and the Panel reported that the scientific and technical libraries are no longer capable of maintaining full collections of technical literature or of providing reasonable facilities for readers. This badly handicaps industrial and other users in keeping abreast of, and

making use of, scientific results, and a greater measure of co-ordinated action is required. The Panel accordingly recommends the establishment of a scientific and technical library authority as a semi-independent agency of the Government to run central and reference libraries, and to advise and assist financially other technical libraries. Its first duty would be to develop a central reference library in London, if possible in close association with specialized libraries of the learned societies, and to develop a national lending library of science and technology, though not necessarily in London.

The Panel considers that the existing Patent Office library might form the basis of the proposed central reference library, and that the existing library of the Science Museum might form the nucleus of the lending library. Better use of the scientific literature in the British Museum Library should also be facilitated. The development of comprehensive scientific and technical sections in public libraries, particularly in the main industrial centres, is also recommended, thus in effect endorsing the recommendation of the McColvin report for the development of regional reference libraries, though the need for a thorough and realistic survey of the whole field of special and non-public libraries is not so clearly recognized, at least in the summary of the report given in the Third Report of the Advisory Council on Scientific Policy.

While agreeing with the diagnosis and broad objectives stated by the Panel, the Advisory Council is not convinced that the case for an executive scientific and technical library authority is established, and considers that the objects in view could be achieved by existing organisations, given effective co-operation and increased support for their efforts. The Advisory Council has accordingly decided to constitute a Standing Scientific Library and Technical Information Committee of the Advisory Council on Scientific Policy. This Committee will be responsible for co-ordinating the development of scientific libraries as a whole and considering in greater detail the parts to be played by individual libraries. It will examine their additional requirements in the light of the needs of users and review the recruitment and training of scientific librarians. It will also initiate and co-ordinate the preparation of union lists and devise and introduce as soon as possible a system of common or interchangeable reader's tickets for those libraries where tickets are required.

In a written Parliamentary answer on July 24, announcing the Government's acceptance of recommendation from the Committee on Industrial Productivity that it should be discharged, the Lord President of the Council confirmed that the Standing Scientific Library and Technical Information Committee set up by the Advisory Council on Scientific Policy would take over the co-ordinating functions hitherto exercised by the Panel on Technical Information Services of the Committee on Industrial Productivity. Without the co-operation of the public libraries the national system of reference and lending libraries in both science and technology desiderated above is unlikely to be built up speedily and efficiently. This undoubtedly is the aspect of public library service of main interest to the scientific worker, though it lies partly outside the sphere of the public library service of the country as inaugurated by the Act of 1850. Clearly the public library service could not well develop one side of its work out of proportion to or at the expense of the rest of its activities. Nevertheless, the value to the economic development of the country of such an extension of the resources of the public libraries for the study of science and technology, whether in their reference or in their lending sections, constitutes a sound reason for more generous Government support of a general expansion. It would be a fitting recognition of the worthy achievements of the first century of the public library.

There are other and more general claims of the public library system on the interest and support of the man of science. If the supply of books is less difficult than during the war years, it is probably still true that both the student and the general reader are dependent to a larger extent on the public library for the books they wish to read than they were before the Second World War. Many standard and classical works are still unobtainable by purchase, although as Sir Stanley Unwin points out in a recent pamphlet, "How Governments Treat Books"*, British restrictions on imports of books except from the hard-currency countries are no longer formidable.

The attitude to books which Sir Stanley attacks in this pamphlet as hindering their free interchange is equally applicable to the extension of public libraries. While post-war governments treat books with the scant respect which Sir Stanley describes, we cannot be optimistic about their encouraging other means which assist the flow of knowledge and of the understanding of one people by another. Furthermore, just as, when books are rare, the importance of the public library which holds them is enhanced, so the present difficult position of the newspapers of Great Britain increases the importance of the reading rooms of the public libraries.

Of the difficult situation in newsprint which has developed in Britain through the mishandling of supplies by the Board of Trade, no more need be said here than that, even if the action now promised by the Government does, contrary to the view of the Newsprint Supply Co., avert the immediate threat of smaller newspapers, British newspapers are still far too small to do their duty to their readers or advertisers, even if they eschewed more rigorously any appearance of waste on the frivolous or trivial. They cannot always supply their readers with the information that is essential for the formation of sound public judgments, even for those who can give the time and trouble to a comparative study of several papers in a public reading room. On that ground alone, while the Government's own policy and control over newsprint supplies prevents the British Press from returning to a size where it could keep its readers well informed on public affairs, it is imperative that the Government should do all that is possible to mitigate the ill-consequences of its own policy.

* How Governments Treat Books. By Sir Stanley Unwin. Pp. 10. (London: George Allen and Unwin Ltd., 1950.) 6d. net.

The centenary of the passing of the first Public Libraries Act is a reminder of one direction at least in which an enlightened and generous policy could do something to promote both the development of the public library system in Great Britain and the formation of instructed and intelligent public opinion on the critical affairs of our time.

ANATOMY OF THE FLOWERING PLANTS

Anatomy of the Dicotyledons

Leaves, Stem and Wood in relation to Taxonomy, with Notes on Economic Uses. By Dr. C. R. Metcalfe and Dr. L. Chalk. Vol. 1. Pp. lxiv+724. Vol. 2. Pp. v+725–1500. (Oxford: Clarendon Press; London: Oxford University Press, 1950.) 126*s*. net.

IN 1671 Nehemiah Grew presented to the Royal Society a manuscript entitled "The Anatomy of Plants Begun", and since that time a vast quantity of information on this subject has been accumulating, more especially during the past fifty years. The present great work by Dr. C. R. Metcalfe and Dr. L. Chalk summarizes present knowledge of the anatomy of the leaves, stems and wood of the dicotyledons and is worthy to rank with Grew's treatise as a classic of botanical science. Botanists throughout the world will be grateful to the authors and to their assistants, Dr. M. M. Chattaway, Dr. C. L. Hare, Miss E. M. Slatter and Mr. F. R. Richardson, for the many years of labour devoted to the production of this monumental work, to their colleagues at the Royal Botanic Gardens, Kew, and the Imperial Forestry Institute, Oxford, where the materials for study have been collected, and to the staff of the Oxford University Press who have printed so excellently these two large volumes.

The prototype of the work was produced by Prof. Solereder and printed in Germany in 1898. It was translated and brought up to date by Boodle and Fritsch in 1908, and was found to be of considerable value to taxonomists and others as a book of reference. But its general utility often proved to be limited because, while devoting much space to details of minor characters, such as the shape of hairs or of crystals found in certain cells, it provided little detailed information about the structure of wood and other features now considered to be of major importance. In the present volumes the observations of Solereder have been considerably condensed and greatly augmented, so that we have virtually a new book.

The main body of the work occupies fifteen hundred closely printed pages in which the vegetative structure of many representative members of the dicotyledonous families is concisely summarized. For each family the information is arranged under the following headings: a general survey of the characters of the vegetative structures and the wood anatomy; details of structure of the leaf, the axis and the wood; anomalous structures; taxonomic notes; economic uses; list of genera studied; literature. While much of the information comes from the observations of the authors, 2,512 references are given to work published since 1908, which, with the literature list in Solereder's work, constitute a comprehensive bibliography of the subject.

The collection and arrangement of the information reflects the modern trends of botanical thought, so that the work is valuable for purposes other than the identification of plant material. In Solereder's time the study of plant anatomy was regarded as a separate discipline with little bearing on plant morphology and physiology; now the different branches of botany have become more closely integrated, and the evolutionary morphologist regards anatomical structure as one of his most valuable sources of information. This change in outlook is well shown in the introduction, where more than thirty pages are devoted to a survey of the progress of anatomy in relation to phylogeny. This valuable summary shows how the study of wood anatomy has provided a basis for views on the evolution of the dicotyledons which are much less open to criticism than theories based on the supposed form of primitive flowers. Assuming that the type of wood found in the gymnosperms is more primitive than that found in the dicotyledons, statistical correlations show which families of flowering plants are likely to be the more primitive and which the more advanced. The application of this method of correlating characters, both vegetative and reproductive, and checking the results when possible with the evidence shown by fossil plants[1], seems likely to bring us nearer to a solution of the problems of the evolution of the angiosperms. Drs. Metcalfe and Chalk have now provided a great fund of information for further studies on the correlation of vegetative characters. Their lists of families in which certain diagnostic characters occur are easier to use than those in Solereder, since they are now printed in tabular form.

The value of anatomical characters in taxonomy is well illustrated by the Rosaceæ. In current systems of classification, this family includes a group of trees and shrubs, chiefly found in America, distinguished as the Chrysobalanoideæ. The latter are stated to be "very uniform in structure and so distinct as to be easily separated from the rest of the Rosaceæ". More than thirty years ago, Juel studied the development of the carpels in the Rosaceæ and found that the carpels of this sub-family originated in a way totally different from that seen in other members of the family. He thought that this showed that the genus *Parinarium* and its allies should no longer be grouped with the Rosaceæ. Although Juel's work seems to have received little attention from taxonomists, it is now clear that his view was fully justified.

Two of the difficulties attending a study of the comparative anatomy and morphology of the flowering plants are the vast number of forms which might be studied and the problem of selecting a representative range of material. Investigations have often been made on the structure of the plants readily available to the worker, and have led to conclusions which were incorrect or inadequate because the forms that were studied were drawn from a restricted range of plants. In the past, much of our knowledge of the anatomy of dicotyledons was based on the study of the herbaceous forms, which probably represent a highly specialized type. The present wide survey should greatly assist workers to select a more complete range of forms possessing the characters which it is desired to study.

While appreciating the value of these two volumes in furthering the more general aspects of plant anatomy and morphology, one must not forget that the main purpose of the work is to assist those who

have to deal with plant material in the identification of their specimens. Those working with timber should obtain considerable help in the identification of hardwoods, based on the study of no less than eighteen hundred species. The details of the structure of leaves and young stems should be of value to those who are examining material imported for use as drugs, flavourings, or other purposes, while the systematic botanist and forester will be supplied with a wealth of information useful in the identification of trees and herbs. The authors have spent ten years in the compilation of the material in this monumental work, and it is not likely to be superseded for very many years. H. HAMSHAW THOMAS

[1] Sporne, *New Phytologist*, **48**, 259 (1949).

BACTERIAL DISEASES OF CROP PLANTS

Manual of Bacterial Plant Diseases

By Dr. W. J. Dowson. Pp. viii+183+32 plates. (London: Adam and Charles Black, Ltd., 1949.) 16*s*. net.

THE honest student of plant pathology will readily admit that there are considerable gaps in his knowledge of bacterial plant pathogens. This is at present no reflexion on his professional zeal, for, since the classical work of Erwin F. Smith, there have been few available collected works on the subject. Methods have, moreover, advanced apace, and knowledge of diseases has increased very greatly. Dr. W. J. Dowson, having experienced this lack of accumulated literature while lecturing, very rightly decided to remove the incubus. He is well qualified to do this, having been, for many years, the specialist to whom almost all the plant pathologists in Great Britain have referred problems on bacterial disease. The result is a thoroughly helpful and authoritative volume.

Perhaps the number of bacterial maladies may seem large to the crop producer; but it should be remembered that Dr. Dowson has drawn a very comprehensive list. Many diseases are described which bring considerable loss in one country but cause little damage in others. All the known bacterial maladies occurring in Britain, and most of those important in the British Dominions, Colonies and Dependencies are included; but a few diseases, recorded so far only from the United States of America, are either omitted or but briefly mentioned. The method of bacterial classification is the author's own modification, but most generic names are already familiar in Great Britain.

A section on methods assumes a knowledge of routine basic methods; but it then becomes a very useful and modern exposition, with all the simple practical features usually developed only by the enthusiast. The platinum needle has, for example, given place to a thin glass rod, with advantage when streaking out plates. Forty excellent half-tone figures illustrate methods, bacteria and disease symptoms, while eighteen world-distribution maps prepared by the Commonwealth Bureau of Mycology make useful contributions in this new setting. Methods for control draw largely on the preventive implications of cultural hygiene; but practical control is probably the least satisfactory section of the subject. This is no criticism of the author or of the book, but rather the *cri de cœur* of an advisory officer at his relative impotence in the face of increasing incidence of bacterial soft rots on agricultural crops. Hygiene is difficult under those conditions, and treatment of dormant organs impracticable.

Plant pathology is, however, only now celebrating the centenary of its inception, and merely its coming-of-age as a vigorous science. Dr. Dowson's book should provide the basis for a considerable impetus to the study of bacterial plant diseases. JOHN GRAINGER

INTENSIVE CULTIVATION OF VEGETABLES

Intensive Salad Production

Including some Vegetables. By C. P. Quarrell. (Agricultural and Horticultural Series.) Fourth revised edition. Pp. xviii+277+16 plates. (London: Crosby Lockwood and Son, Ltd., 1949.) 15*s*. net.

TO the commercial grower and to the student a new edition of C. P. Quarrell's book is a matter of some importance. This is something more than a mere revision of the earlier editions; it is almost a new book. There could not be a better illustration of the rapidity with which horticultural knowledge has grown since the Second World War than the changes which four years have necessitated in the text. Up to 1945 (the date of the third edition) intensive salad production meant almost exclusively the Dutch-light systems pioneered in Great Britain by Mr. F. A. Secrett. Since that date a multitude of other types of protective devices have appeared—cloches, frames and structures of different kinds, sizes and shapes in bewildering variety—and many of these have proved themselves of economic value to the commercial grower. Their adoption has meant new cropping systems and the introduction of a greater diversity of crops into the rotations, and new varieties of plants have been produced to meet the changed needs.

The introduction of entirely new synthetic insecticides and fungicides, the astonishingly rapid growth in the use of overhead irrigation and the development by the British Electrical and Allied Industries Research Association of low-voltage electrical methods of soil warming have all made this new edition imperative. There is scarcely any branch of horticultural production to which the results of war-time and post-war research have been more usefully applied than to protected cultivation. Quarrell's book has become the standard reference for the grower and the chief source of study in this field for the student, and he has earned a debt of gratitude by preparing this careful revision. The photographs and diagrams have been most carefully chosen to illustrate the text; but the addition of a few diagrams to illustrate the section on soil warming by electricity would have been of great value.

For ease of reference it would be an improvement to divide the section on diseases into two chapters and to print the name of the host plant in larger type than that of the parasite. Though cultivation of salad crops in glasshouses is dealt with, no mention is made of the new insecticidal smokes and continuous-phase aerosols which show so much promise in labour saving. Not the least valuable part of the volume as a reference book is the final section of tables, miscellaneous data and selected references to the literature, which bring together much that is so often difficult to find. R. H. STOUGHTON

RECENT ADVANCES IN PHYSICS

Reports on Progress in Physics

Vol. 12 (1948–49). Pp. iii+382. (London: Physical Society, 1949.) 42*s*. net; to Fellows, 25*s*. net.

IN recent years almost every branch of physics has been expanded considerably. Furthermore, the volume of scientific publications has increased to such a large extent that even the specialist in the narrowest field finds it difficult to keep in touch with the rapid developments in his own subject. To follow, in addition, major advances in other important branches of physics is practically impossible. The need, therefore, for the publication at frequent intervals of specialist surveys and reviews of the different fields of physics, such as those provided by "Reports on Progress in Physics", could not be greater. The welcome return, with the publication of Vol. 11 in 1948, the present work in 1949 and the appearance of Vol. 13 in the very near future, to the annual series from the temporary two-year volumes is not only a matter for congratulation but also indicates that the Physical Society is fully alive to the growth of physics and the needs of physicists.

As in previous volumes, the fourteen articles contained in Vol. 12 are authoritative and masterly contributions written by well-known experts in their respective subjects. It is a moot point, however, whether the author of a report should consider his reader to be a specialist worker in that particular field or a trained physicist seeking an insight into, and understanding of, the recent advances in other branches of physics than that peculiarly his own. Both kinds of reports would be equally useful. It is impossible, however, to tell from the title alone into which of these two categories any one of the reports of Vol. 12 falls. In some, as a welcome innovation, a contents list has been provided, and in a few, also, an abstract, so that an idea of the scope of a particular report can be obtained at a glance. But it is a pity that the editor has not insisted on uniformity in this connexion. The provision of an abstract is most helpful, if not essential, and the insertion, at the editorial stage, of a contents list for each report is surely a simple matter.

As usual the contributions cover advances in both the experimental and theoretical fields. On the experimental side there are articles on mass spectrometry; nuclear paramagnetism; phosphors and phosphorescence; nuclear experiments with high-voltage X-rays, in which nuclear physical experiments carried out with betatrons and synchrotrons are described; linear accelerators in which both electron accelerators and the standing-wave proton accelerator are dealt with; and on low-temperature physics in which K. Mendlessohn very rightly restricts his attention to the recent advances in technique and to the two physical phenomena peculiar to low temperatures, namely, superconductivity and superfluidity.

On the theoretical side the volume contains several reports of interest, including one on the theory of oxidation by N. Cabrera and N. F. Mott, and one on collisions between atoms and molecules at ordinary temperatures by H. S. W. Massey. In addition, there are two rather longer articles which are more of the class of monographs than reports. The first, by E. Orowan, is on the fracture and strength of solids. In some forty-five pages, after outlining the main types of fracture, a detailed discussion is given of ultimate stress and necking; brittle fracture, ductile fractures and notch brittleness; fatigue; intercrystalline fractures and fracture by molecular sliding. The second, which is even longer, is by J. de Boer, on molecular distribution and the equation of state of gases. Both the kinetic method and the method of statistical mechanics are clearly explained. A section of a more practical nature follows, and, in order not to lengthen the treatment too much, only the application to the calculation of the distribution-function and the caloric and thermal equation of state of gases, and the properties of systems in equilibrium are discussed.

Three other reports call for special comment. The first, "Spontaneous Fluctuations", by D. K. C. MacDonald, will be of interest both to pure and electronic physicists. It is an account of 'noise' in electrical circuits, in valves and in semi-conductors. Particular attention is paid to the most recent developments. The second, by G. O. Jones, on viscosity and related properties in glass, which was originally presented before the Physical Society as a lecture survey on February 15, 1946, should appeal to the general reader as well as the glass technologist. The flow properties of glass are of obvious practical importance, but, since glass can be regarded as a liquid even at temperatures where it most closely resembles a solid, it is also of considerable theoretical interest. The structure and general properties of glass are briefly considered, and then the significance of phenomena in the transformation region. Finally, the report by M. Ross and J. S. Story on slow-neutron absorption cross-sections of the elements is nothing more than a list of published declassified numerical values, and, though of considerable value, seems out of place in "Progress Reports".

All the excellent features present in previous issues appear in Vol. 12, including the extensive bibliographies, the author index, the clear line-diagrams and beautifully reproduced photographs. The paper, printing and binding are of the highest standard and similar to those of the Physical Society's *Proceedings* and its other publications. The "Reports" are an essential reference work, and no library or active physicist can afford to be without a copy.

S. WEINTROUB

AN ALPHABETICAL GUIDE TO ATOMIC ENERGY

Pocket Encyclopedia of Atomic Energy

Edited by Frank Gaynor. Pp. 204. (New York: Philosophical Library, Inc., 1950.) 7.50 dollars

THIS book consists of about two thousand definitions or short explanations of terms which are commonly used in discussing atomic energy and nuclear physics. The entries vary in length from a few words to a few pages, and are supplemented by about thirty-five diagrams and tables. There are also brief descriptions of some of the more important nuclear research laboratories and biographical sketches of a few well-known men of science. German equivalents are given for the majority of the terms which have been included.

The intrusion of highly specialized expressions from nuclear physics and engineering into wide fields of politics, administration and technology fully justifies the preparation of such a glossary. Many

persons whose education was not scientific, or whose technical training was received when nuclear physics was an abstruse speciality, now find themselves compelled to understand and use a great number of terms which are defined in this volume. A work of this kind should therefore be clear, comprehensive and accurate, and should confine itself to its own subject. There do not appear to be many omissions in the fields of physics and engineering, though *nuclide* and *thermal column*, for example, are missing; I have the impression that the chemical and biological sciences are not so well covered. The standard of writing varies very greatly. The majority of the entries are well expressed and, considering the limits imposed by brevity and simplicity, are not misleading. Some parts, however, sink far below the standard required in a work of any scientific pretensions. Thus, the most important portion of the description of Geiger–Müller counters runs as follows: "The modern version of this counter is an oblong box with headphones attached to it. When a fast alpha or beta particle enters the apparatus, it produces ions in the gas contained in it, and ions cause a loud tick to be heard in the headphone; the ticks are counted automatically by a mechanical device. A modern Geiger–Müller counter can count several hundred thousand particles per minute." It is a pity that much careful work should be marred by such lapses.

The standard of accuracy is not as high as one has a right to expect; nine misprints or errors were found in fifty entries which had been selected more or less at random. Most of the information is creditably up to date; but it is not always as authentic as possible. For example, Seaborg and Perlman's Table of Isotopes (*Rev. Mod. Phys.*, **20**, 585; 1948) is not mentioned, and the properties of the radioactive nuclei are quoted from a medical text-book. In a future work of this type, in which a really authoritative treatment is plainly impossible, it would probably be worth while to give references, wherever possible, to standard text-books or to review articles. At present a reader who wishes to inquire further has no idea where to begin.

The price of this volume is almost prohibitively high for the 'sterling' reader. It must therefore be regretted that so much space is devoted to duplicating information which can be found in any chemical dictionary. In so rapidly changing a field, and one in which the latest developments are of interest to a larger public, a smaller book, more easily renewed, would have been preferable.

W. J. WHITEHOUSE

PRESENTATION OF INORGANIC CHEMISTRY

The Chemical Elements and their Compounds

By N. V. Sidgwick. Vol. 1. Pp. xxxii+854. Vol. 2. Pp. vi+855–1704. (Oxford: Clarendon Press; London: Oxford University Press, 1950.) 70s. net.

THE presentation of inorganic chemistry to the undergraduate and research worker raises problems of peculiar difficulty, for the mass of factual detail which has accumulated tends to obscure the general principles which are gradually emerging. At the same time a certain amount of detail is inevitable, if only by way of illustration of principles. Prof. N. V. Sidgwick has approached this problem by omitting almost completely mineralogy, metallurgy and technical and analytical chemistry. With this simplification, the elements are then dealt with in turn on the basis of the Periodic Table, those of Groups I–V in the first volume and the remainder in the second volume. Some of the elements, such as boron, phosphorus and a number of the metals, are treated individually; but certain groups of closely related elements, such as arsenic, antimony and bismuth, or the halogens, are taken together. This has enabled special emphasis to be placed on comparative chemistry and the variations in properties within the groups. Problems of interest in connexion with valency and structure are brought well to the fore, as are the many instances where further investigation is needed. The author has succeeded completely in his aim of emphasizing principles: the remarkable thing is that he has also included a tremendous amount of interesting descriptive chemistry without at any point overburdening the text with detail. The treatment of carbon is particularly valuable, for not only has it taken its place as a normal element, but also a good deal of space is devoted throughout the book to organic derivatives.

Numerous references are given and their arrangement at the foot of each page is very convenient. The literature survey has been completed up to the summer of 1948. Only in the case of a few topics, such, for example, as the chemistry of the transuranic elements and the use of lithium aluminium hydride, where recent progress has been unusually rapid, are there significant omissions. The index is good, though it would have been more convenient had it been printed in full at the end of each volume, instead of in the second only.

Criticism of the author's choice of material can only be a matter of personal opinion. Some readers may, however, regret that so little reference is made to the experimental aspects of inorganic chemistry. One finds very frequently, especially among undergraduates, a more or less adequate knowledge of facts and theories, but a complete ignorance of how any but the most elementary experiments are done. Another point on which comment is perhaps justified is the very slight emphasis which is placed on physicochemical aspects of the subject, such as the significance of oxidation-reduction potentials and equilibrium data. Structural inorganic chemistry is also given little prominence, but one feels here that the author may have expected the reader to have available A. F. Wells's excellent book on this subject, which was published in 1945 by the Oxford University Press.

The book reflects accurately Prof. Sidgwick's lifelong interest in chemistry as a whole. For undertaking this task and bringing it to so satisfactory a conclusion he deserves the particular gratitude of those who teach inorganic chemistry. The subject has long needed pruning, so as to separate much of the accumulated information which belongs properly to reference books, and reveal the underlying principles and the lines along which progress can be made. Few are better qualified to do this than the author: probably no one else could have produced in the process a book which, from cover to cover, is so readable. It is certain to be widely used by undergraduates, teachers and research workers, and to stimulate an interest which will lead to a more rapid advance in the correlation and interpretation of the facts of inorganic chemistry. H. J. EMELÉUS

Foraminifera

Their Classification and Economic Use. By Joseph A. Cushman. Fourth edition, revised and enlarged, with an Illustrated Key to the Genera. Pp. viii+605 (86 plates). (Cambridge, Mass.: Harvard University Press; London: Oxford University Press, 1948.) 55*s*. net.

A LEGACY to science of more than five hundred works on the Foraminifera has been left by the late Dr. J. A. Cushman, and, of these, there is little doubt that "Foraminifera: their Classification and Economic Use" (fourth edition) is of most general value both to the student, the research worker and the petroleum micropalæontologist. Each edition, as it appeared, was regarded as the main standby of modern knowledge of the genera of Foraminifera, and, although Cushman's division of them into families and natural groups is not necessarily acceptable to all, at least he has adhered to a constant main grouping throughout successive editions and, indeed, in all his works.

About 750 genera are defined and figured in the new edition and many recently described have been incorporated. It is good to see among his inclusions the genus *Fabiana* Silvestri, which was originally described as an Eocene coral. It is a pity that *Nummulostegina*, a Carboniferous genus, should have been defined and figured twice: once under the Fusulinidæ—the contribution on this family being made by Dr. Carl O. Dunbar—and again under the Camerinidæ [=Nummulitidæ]. Dr. Cushman and Dr. Dunbar would have done well to have conferred on this matter.

Many points of taxonomic interest could be debated; but it is easier to criticize than to construct, and in all fairness it is no exaggeration to say that Dr. Cushman's book is the most comprehensive, up-to-date text-book on the Foraminifera, and it marks the climax of the author's distinguished career.

C. D. OVEY

Wildfowling

By James Andrews, T. Clifford Bland, Robert Blockley, Robin Farmiloe, Robin Harrison, John Inge, Christopher Lee-Elliott, Alastair McArthur, Douglas Service and Michael Shephard. (Lonsdale Library of Sports, Games and Pastimes, Vol. 29.) Pp. 352+49 plates. (London: Seeley, Service and Co., Ltd., n.d.) 25*s*. net.

VOLUME twenty-nine of the Lonsdale Library is devoted to "Wildfowling", a team of ten writers having collaborated to produce it, each dealing with a section of which he has special knowledge. For example, Robert Blockley writes of geese, ducks, waders and so on, in short, the birds commonly spoken of as waterfowl, from the ornithological point of view, giving a brief description of the appearance, distribution, habitat, habits and food of each species; while T. Clifford Bland deals with shoulder guns and punt guns. Then Christopher Lee-Elliott gives us a note on the legal aspect of wildfowling; and John Inge writes at length on the practice of the sport, giving the beginner and those who are not beginners alike much useful information and helpful advice. There are also chapters on punts and punting by Douglas Service, Michael Shephard following with five chapters on "Inland Marsh Shooting". We then come to chapters on "Decoy Ponds" by Robin Farmiloe; on "Wildfowling on a Norfolk Estuary" by Robin Harrison; the "Hawking of Wildfowl" by Alastair McArthur; and lastly one on "First Aid and Shooting Accidents" by James Andrews. A glossary of wildfowl terms and a comprehensive index wind up the volume.

Where so much pains have been taken, where so wide a field has been covered and so much helpful information supplied, it seems a pity a little time was not devoted to the revision of details, for example, in the glossary we read "marram grass: see Zostera marina"! And surely the term "eyass" is and was used by falconers to denote a young hawk and not merely "fledglings captured by the setting of a snare"?

FRANCES PITT

Britain's Beasts of Prey

By W. Kay Robinson. Pp. 128. (London: Latimer House, Ltd., 1949.) 7*s*. 6*d*. net.

THIS very readable book relates many little-known facts about British mammals that are threatened with extinction, together with claims for and against hunting them. The author quotes many fascinating stories about those disappearing species, the wild cat, pine marten and polecat, written in the pleasantly informative style with which followers of his very popular newspaper articles are familiar. He presents a strong argument in favour of that much-persecuted animal, the otter, proving that on streams where it is protected the fishing is improved, and condemning the senseless killing of one of the most useful wild animals in Great Britain.

OLIVER G. PIKE

Gmelins Handbuch der anorganischen Chemie

Achte völlig neu bearbeitete Auflage. System-Nummer 10: Selen. Teil B: Die Verbindungen des Selens. Pp. xxi+vii+195. (Clausthal-Zellerfeld: Gmelin-Verlag G.m.b.H., 1949.) n.p.

THE reappearance of this famous work is a welcome event. No other book can be compared with it in its field, and the standard of the new parts is as high as that of previous volumes. This particular part deals with the compounds of selenium with hydrogen, oxygen, nitrogen, halogens and sulphur. By reason of the scheme of arrangement, selenites and selenates must be looked for in other volumes dealing with the metals. The mode of treatment takes full account of the physics and physical chemistry of the substances. The copy sent for review was much disfigured by excessive rubber-stamping.

J. R. P.

Ions, Electrons and Ionizing Radiations

By Prof. James Arnold Crowther. Eighth edition. Pp. ix+322+7 plates. (London: Edward Arnold and Co., 1949.) 21*s*. net.

SINCE 1919, when it first appeared, this book has served many generations of students as an introduction to the major treatises on atomic physics. The earlier editions were noteworthy for the emphasis given to the pioneer work of Rutherford, Thomson, Townsend, and the others who laid the foundations of the subject; and this invaluable feature has not been sacrificed in the eighth edition, which carries the account of the main lines of progress up to the present time. The problem of selection for each successive edition must have become more and more difficult as the subject developed. It is sad to relate that, by the recent death of Prof. J. A. Crowther (see *Nature*, May 13, p. 250), this edition marks the last to be revised at his hands, for in it the author's judgment has been as happily exercised as ever.

G. R. NOAKES

TRANSPLANTATION OF NUCLEI FROM CELL TO CELL

By Dr. I. J. LORCH and Prof. J. F. DANIELLI

Chester Beatty Research Institute, Royal Cancer Hospital, and the Department of Zoology, King's College, London, W.C.2

WHILE it is generally agreed that most of the factors so far studied which determine the character of an organism are part of, or attached to, chromosomes, in the last decade or so a considerable body of evidence has come to light showing that some of these factors are not directly associated with the chromosomes. Much of this evidence has been reviewed recently by Mather[1] and by Caspari[2]. One of the main experimental methods available for studying these factors is the use of mating.

In the field of differentiation, opinion has developed rather differently, inclining strongly to the view that the differences between the differentiated cell types of the same organism are produced by changes in the cytoplasm, and are maintained by the cytoplasm. Thus, it is commonly supposed that, apart from the intrusion of such phenomena as polyploidy and polyteny, the nuclei of all the somatic cells and germ-line cells (but not the germ cells themselves) have an identical gene constitution. As techniques based on mating are not available for studying somatic cells, it is difficult to test this supposition. On the other hand, it is quite clear that the characters of differentiated cells are in part determined genetically; when an animal displays a mosaic character in a tissue which is normally homogeneous, the mosaic is commonly attributed to mutation during development. In some cases mutation can probably be observed in a single somatic cell[3]. It is thus recognized that mutation, even in a very late stage of development, may markedly affect the character of a differentiating cell. The importance of the nucleus at the earliest stages of differentiation is shown by the experiments of E. B. Harvey[4] on enucleated sea urchin eggs. Enucleated eggs, when artificially activated, divide to give a crude blastula of up to 250 cells, but will not show any sign of differentiation. Many facts also attest to the quantitative importance of the nuclear factors; the action of a gene on differentiation may vary according to the number of genes of a particular type in the chromosome structure. When these considerations are weighed, it is clear that there is inadequate evidence of the extent to which differentiation is initiated by, and maintained by, the nucleus and cytoplasm respectively.

The simplest way to obtain unequivocal evidence of the extent to which irreversible changes occur in nuclei and cytoplasm during differentiation would be to transplant nuclei and cytoplasm from one type of cell to another. This presents a number of technical difficulties. But that the procedure is not impossible is shown by the work of Commandon and de Fonbrune[5], who transplanted nuclei from cell to cell in *Amœba sphæronucleus*. Their procedure was to remove the nucleus from one individual by pushing the nucleus out of the cell with a blunt microdissection needle—this involved a very small loss of cytoplasm. Then a nucleus was transferred into the enucleated cytoplasm from a second nucleated cell. A very small transfer of cytoplasm must have occurred at the same time.

Our first experiments have been with *Amœba proteus* and *Amœba discoides*, stocks of which were kindly given to us by Sister Monica Taylor and Sister Carmela Hayes. Mass cultures were grown from single individuals. These two species are not so convenient for microdissection as is *A. sphæronucleus*, but have the advantage that mass cultures can readily be grown from single individuals under laboratory conditions, whereas according to de Fonbrune this is not so with *A. sphæronucleus*. We have made transfers of nuclei both between individuals of the same species (homotransfers) and individuals of different species (heterotransfers).

For convenience in reference, a symbolism has been used: thus $P_n \rightarrow D_c$ indicates transfer of a *proteus* nucleus to *discoides* cytoplasm. The general procedure was to remove a nucleus from an amœba and transfer a nucleus from a second cell within ten minutes, using the technique of Commandon and de Fonbrune. The animal was then placed in a watch glass containing a rich culture of *Chilomonas* in Chalkley's fluid. If the animal multiplied, the culture was transferred to a Petri dish when 50–100 cells were present, and to a large 'Pyrex' dish when the Petri dish was becoming crowded.

When an amœba is enucleated, the cytoplasm assumes the form of a sphere with numerous short blunt pseudopods. When transferred to a watch-glass some recovery takes place, and short periods of amœboid movement alternate with periods of quiescence and unco-ordinated cytoplasmic streaming. After some days, the cell again becomes rounded, with short pseudopodia, and rarely lives more than twenty days. When a nucleus is transferred successfully, normal appearance and ability to move may be recovered in a few seconds, though several hours may elapse before recovery is complete in the case of some animals. In the subsequent discussion, an animal which has undergone this change is referred to as 'reactivated'.

Type of transfer	Homotransfers		Heterotransfers	
	$P_n \rightarrow P_c$	$D_n \rightarrow D_c$	$D_n \rightarrow P_c$	$P_n \rightarrow D_c$
Number of transfers	55	52	60	61
Number of amœbæ reactivated	52	42	51	45
Number of amœbæ dividing at least once	37	38	22	3
Number of amœbæ giving mass cultures	34	37	0	1

The accompanying table gives a summary of the results obtained by nuclear transfer. With homotransfers, about 90 per cent of animals were reactivated. Of those reactivated, the great majority divided at least once. Of the animals which divided once, more than 90 per cent eventually produced mass cultures; that is, about 65 per cent of the nuclear transfers were completely successful.

With heterotransfers, about 80 per cent of animals were reactivated, and there was no great difference between homo- and hetero-transfers in this respect. With the transfer $D_n \rightarrow P_c$, only about 40 per cent of the reactivated animals divided once or more, and no mass cultures were obtained from sixty transfers.

With the transfer $P_n \rightarrow D_c$, only three out of sixty-one animals divided once or more, and only one of these gave a mass culture.

A. discoides and *A. proteus* differ in a number of particulars; so far we have studied the effect of nuclear transfer on two of these differences, namely, nuclear diameter, and form assumed when moving. After division, the nuclear volume is at a minimum, and growth of the nucleus occurs to roughly twice the volume after division, before further division occurs. Consequently, in order to obtain a significant figure for the nuclear diameter of a particular stock, it is necessary to make measurements on a number of individuals. The nuclei of the species we studied are not symmetrical, so the largest diameter was measured. For *A. proteus* the largest diameter of the nucleus of our stock was $41 \pm 5\mu$, and for *A. discoides* $33 \pm 2{\cdot}6\mu$.

With the transfer $D_n \rightarrow P_c$, twelve nuclei were measured immediately before transfer, and again twenty-four hours later. The average of the initial diameters was 33μ, which is the average for *A. discoides*. After twenty-four hours, the average diameter had increased to 39μ: this is outside the range for *A. discoides* ($33 \pm 2{\cdot}6\mu$) and within the range of *A. proteus* ($41 \pm 5\mu$).

With the transfers $P_n \rightarrow D_c$ which did not give a mass culture, thirteen measurements were made on ten individuals which were the progeny of two transfers, at various times (up to twenty-eight days) after transfer. Although the measurements showed that any individual nucleus grew, before dividing, the average diameter after transfer was 38μ, that is, still within the *proteus* range, though on the low side, since the nuclei were more than 40μ before transfer.

With the transfer $P_n \rightarrow D_c$ which gave a mass culture, numerous measurements of nuclear diameter were made, at fortnightly intervals. The average diameter was $33 \pm 3{\cdot}3\mu$, which is practically identical with the value characteristic of the pure *discoides* line ($33 \pm 2{\cdot}6\mu$).

It must be emphasized that when a clone is derived from one individual of another clone, the average nuclear diameter of members of the new clone is not dependent upon the diameter of the nucleus of the individual amœba used to start the new clone. A clone of *A. proteus* grown from an amœba of nuclear diameter of 35μ has the same average diameter as a clone grown from another individual which, when chosen from the same parent clone, had a diameter of 45μ. Thus the variations which are observed after nuclear transfer cannot be attributed to variations in the size of the nucleus at the time of transfer.

From these measurements a marked tendency is evident for the nuclear diameter to be determined in part by the cytoplasm.

Studies of the form of moving amœbæ were made by tracing the outline of individuals, at intervals, using a camera lucida. The outline of *A. discoides* is characteristically more serrated than is that of *A. proteus*, and unlabelled drawings are readily sorted into the two species by inspection of the outline. When the outlines of individuals from the mass culture resulting from the transfer $P_n \rightarrow D_c$ were examined, the outlines fell between the *discoides* and *proteus* forms. When different observers were given a mixed collection of outlines of *proteus*, *discoides* and $P_n \rightarrow D_c$, some classified the heterotransfer as *discoides* or *proteus*, and other observers preferred to group the heterotransfer outlines in a third group.

From this result it appears that the form assumed by an amœba in movement is in part determined by the nucleus, and in part by the cytoplasm.

Our results show that when nuclei are transferred from one amœba to another of the same species, the transfer can be successful in a high proportion of cases. Activation of the cytoplasm, division, and formation of mass cultures occur readily.

When nuclei are transferred from one species to another, activation occurs readily. But nuclear and cell division occur much less readily than with homotransfers, and formation of a mass culture is rare. Nevertheless, nuclei of either species can grow, divide, and cause cell division, after transfer to the cytoplasm of another species.

Studies of nuclear diameter and of form when moving both suggest that the cytoplasm has an important influence. The culture $P_n \rightarrow D_c$ has now been maintained for more than a year, but still shows no sign of closer approximation to the *proteus* type. Much further work is needed, and more characters must be studied, before it will be wise to base any generalizations on these experiments.

We are deeply indebted to: Prof. A. Haddow, Dr. J. A. Kitching, Prof. H. G. Callan, Sister Monica Taylor and Sister Carmela Hayes, for help and advice, and to the British Empire Cancer Campaign for financial support.

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FRICTION*

By Dr. F. P. BOWDEN, F.R.S.

Research Laboratory on the Physics and Chemistry of Rubbing Solids, Department of Physical Chemistry, Cambridge

IF we slide one solid body over another, there is a resistance to the motion which we call friction. What is the cause of this, and what is really happening at the interface between the solids during sliding? It is usually considered that friction is a nuisance, and from earliest times man has made ingenious attempts to eliminate or to diminish it to as small a value as possible. It is not so much the work we have to do in overcoming friction—the power loss—which is important, although this can be considerable. In a modern motor-car, for example, about 20 per cent of the power is wasted in overcoming friction. In an aeroplane piston engine it is about 9 per cent, and in a modern turbo jet engine it is about 1½–2 per cent. The real trouble is the damage that is done by friction—the wear or seizure of some vital part of the machine. It is this factor, perhaps more than any other, which limits the design and which shortens the effective working life of, say, an aero-engine or other complex machine. Nevertheless, the credit side is considerable: if the coefficient of friction were much less than it is, walking would be impossible and we should have to use cog wheels or perhaps some system of suction pads like an octopus to get about at all. Conversely, if it were much higher than it is, we should just stick fast wherever we were put.

* From a Friday Evening Discourse at the Royal Institution, delivered on May 19.

There are two basic laws of friction. The first of them says that the frictional resistance is independent of the area of the sliding surfaces, and the second that it is proportional to the load between them. It would seem that Leonardo da Vinci (1452–1519), with his astonishing practical genius and insight, was clear about them, for he writes: "The friction made by the same weight will be of equal resistance at the beginning of the movement although the contact may be of different breadths or lengths", and "Friction produces double the amount of effort if the weight be doubled". The rediscovery of these laws by the French engineer Amontons in 1699 was, however, received with some surprise and scepticism by the Royal Academy of Sciences in Paris.

Since the friction is proportional to the load, we may define the coefficient of friction as the ratio

$$\frac{\text{the frictional force}}{\text{the applied load}}.$$

For a brick sliding on wood, the coefficient of friction is about 0·5; for clean metals in air, it is about 0·5 to 1; for boundary lubricated metals, about 0·1.

Amontons's observations were verified by Coulomb in 1781, who made a clear distinction between static friction, the force required to start sliding, and kinetic friction, the force required to maintain it. He showed that kinetic friction could be appreciably lower than static friction and made the observation, which is sometimes quoted as a third law, that the kinetic friction is nearly independent of the speed of sliding. Coulomb considered the possibility that friction might be due to molecular adhesion between the surfaces, but rejected it on the grounds that if this were so the friction should be proportional to the area of the sliding bodies, whereas it was found to be independent of it. He concluded that the friction was due to the inter-locking of the surface asperities and represented, in the main, the work of lifting the load over the summits of these asperities. He had some reservations about this theory, but he hesitated to speculate further because, as he pointed out, the Royal Academy of Sciences only wanted useful results, not theories. I hope to show that that first view is, in fact, more correct, and that friction is due in a large measure to adhesion between the surfaces.

In recent times experimental investigations in friction, particularly of static friction of solids lubricated with very thin films of hydrocarbon, were made by Sir William Hardy. In particular, Hardy showed the important part played by a single molecular layer of lubricant (the boundary layer). His own experiments were elegant and simple, and he emphasized the necessity for applying modern physical and chemical concepts and methods to the study of these surface phenomena. It is perhaps Hardy's work more than any other that stimulated a modern approach to the subject.

Area of Contact between Solids

Now the first question we may ask is this: What is the real area of contact between solids?

It is a very difficult matter to prepare surfaces which are really flat; even on carefully polished surfaces, hills and valleys are present which are very large in comparison with the size of a molecule. If two solids are placed in contact, the upper surface will be supported on the summits of the irregularities and large areas of the surface will be separated by a distance which is great compared with the molecular

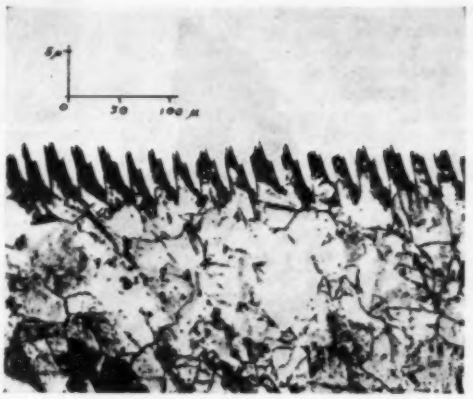


Fig. 1. Oblique section of finely turned copper surface. Vertical magnification × 1,800, horizontal magnification × 175. Height of surface irregularities about 50,000 angstroms

range of action. Even with modern techniques of cleaning and polishing, it is still a difficult matter to prepare surfaces of appreciable size which are flat to within 100–1,000 angstroms. Most of the surfaces used in engineering practice have surface irregularities which are much greater than this. Our first point of investigation was therefore into the shape and size of these irregularities, in an attempt to determine what is the real area of contact between solids. In addition to the use of a stylus instrument such as the Talysurf, various methods are being employed for investigating this problem. The first method consists simply of cutting a section through the solid and looking at the surface irregularities under a microscope. A simple technique is, however, used to increase the sensitivity of the method. If, instead of cutting the section at right angles to the surface, it is cut at an angle of a few degrees, the effect is to magnify the irregularities in a vertical direction by a factor of ten or so, leaving the horizontal magnification unchanged (see Fig. 1).

The second method is the use of the electron microscope. This is, for certain purposes, a much more powerful tool and can resolve detail down to about 20 angstroms. The electron microscope shows that the smoothest surface we have been able to prepare by electrolytic polishing still has hills on it which may be several hundred angstroms high.

A third method depends on interference of waves of light. With the ordinary two-beam interference method, the light and dark interference bands are comparatively broad and diffuse. Tolansky has recently developed interference methods to a high degree of sensitivity by making the surfaces highly reflecting and using multiple reflexion. This has the effect of making the interference lines very sharp, so that very fine detail on the surfaces can be revealed. It is even possible to detect steps on the surface which are only two or three angstroms high, and an examination of cleaved crystals shows that they have steps on them some hundreds or even thousands of angstroms in height.

It is clear from all these measurements that the real area of contact between solids will be very small. Putting two solids together is rather like turning Switzerland upside down and standing it on Austria. Some knowledge of the area in contact is essential for our purpose, and its determination is a matter of

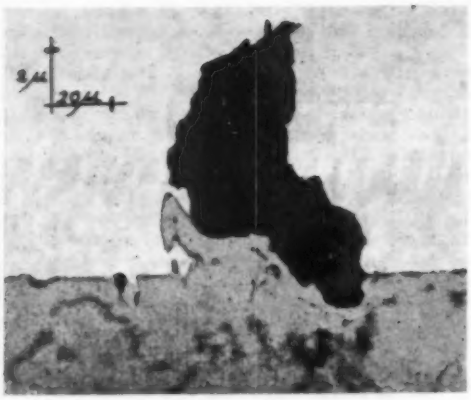


Fig. 2. Oblique section of steel surface after copper slider has passed over it once. Vertical magnification × 4,200, horizontal magnification × 410. Copper fragment (dark colour) is adhering to steel. Note how it has pulled the steel up above the surface

some experimental difficulty. Fortunately, with metals an approximate estimate of it can be made by measuring the electrical resistance across the surface of the metals when they are in contact. If the metals touch at a number of points, the electric current will be carried across at these points, and by measuring the electrical resistance it is possible to form an estimate of their size. The results show that the real area of contact is indeed very small; it varies with the load, but for flat steel surfaces it may be less than one ten-thousandth of the apparent area. The experiments are also interesting in that *they show that the real area of contact is almost independent of the size of the surfaces*. It is also very little influenced by the shape and degree of roughness of the surfaces. It depends mainly on the load which is applied to them, and is, in fact, *directly proportional to the load*. The general behaviour is consistent with the view that the surfaces are held apart by small irregularities. This means that, even with lightly loaded surfaces, the local pressure at these small points of contact is very high, and may be sufficiently great to cause steel to flow plastically. Although the stresses will cause elastic deformation of the metal in the vicinity of the points of contact, the experiments suggest that the summits of irregularities on which the bodies are supported flow plastically, and are crushed down until their cross-section is sufficient to enable them to support the applied load. These experiments offer an explanation of the first 'law': since the real area of contact between the solids is independent of the actual size of the surfaces, we should also expect that the friction would be independent of their actual size. Also, since the real area of contact is proportional to the applied load, it offers an explanation of the second 'law'.

The fact that the real area of contact is so small has important practical implications. Even when loads of only a few hundred grams are applied to the surfaces, the local *pressure* between them may be sufficiently great to cause the flow of metal. When large flat surfaces are used, it does not mean that the real pressure is much less, but merely that the points of contact are more widely distributed. This intense pressure will cause an adhesion or 'pressure welding' at the tiny points of contact and so produce small metallic junctions between the surfaces. The reality of these localized adhesions may be shown in a number of ways. If, for example, we slide a piece of copper over steel, and then examine the surface by the taper section method, we may detect fragments of copper which are adhering to the steel (Fig. 2). Another sensitive method of doing this is to use, as a slider, an artificially radioactive metal. If this localized adhesion takes place, small fragments of the radioactive metal will be welded on to the other surface, and we may detect their presence either by a Geiger counter or by an auto-photographic method (Fig. 3).

There is strong evidence that the friction of metals is due, in a large measure, to these localized adhesions and represents the force necessary to shear these small junctions.

Friction and Adhesion

If this localized welding occurs between the metals when they are placed in contact under an applied load, we might expect that when the load is removed the surfaces should continue to adhere, and that an appreciable *normal* force will be required to separate them. If, however, we perform this experiment with reasonably hard metals such as steel and copper, we find no evidence for any such adhesion. Why is this? It is suggested that the explanation is a simple one. Although the metal is deformed plastically at the points of contact, there will be elastic deformation in the bulk of the metal near by. When the load is removed, these elastic stresses will be released and the resulting displacement will break any junctions that may have been formed. This view is confirmed by experiments with soft metals, such as indium and lead, where the released elastic stresses are very much less. In fact, we find with these soft metals that the normal force required to separate the surfaces is very nearly the same as the tangential force required to slide them; that is to say, the coefficient of adhesion and the coefficient of friction are approximately the same. The effect of a lubricant film, even of a monolayer, will reduce the adhesion to a very small value. We have therefore a close correlation between friction and adhesion.

General Effect of Surface Films

There is another observation of Leonardo da Vinci's which is very relevant to our purpose. He

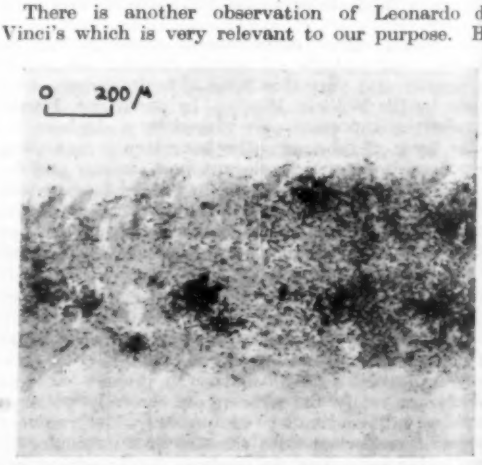


Fig. 3. Autoradiograph of track formed when artificially radioactive copper is slid over lubricated copper surface once. Magnification × 50. Dark spots show where copper from slider is adhering to lower surface. Surface concentration approximately 10^{-6} gm. per mm.^{2}

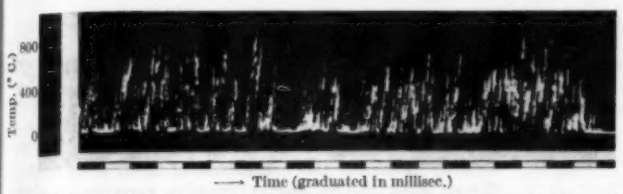


Fig. 4. Surface temperature developed with a constantan slider on a finely ground steel surface. Load 500 gm. Speed of sliding 300 cm. per sec. The temperature flashes may be as high as 1,000° C. and are of very short duration

writes: "All things and everything whatsoever, however thin it be, which is interposed in the middle between objects that rub together, lighten the difficulty of this friction". The experiments which we have described have been carried out on surfaces which have been very carefully cleaned. We know, however, that when metals are exposed to the air, their surfaces are covered by a thin film of oxide which is at least several molecular layers in thickness. It is very difficult to remove the last adsorbed layer, and we can only achieve it by heating the metal to a very high temperature in a vacuum. If we perform this experimentally, we find there is, indeed, a profound change in the friction.

If two pieces of metal are heated in a high vacuum, so that all surface films are driven off, and are then allowed to cool and placed in contact, it is found that immediate and complete seizure occurs. The coefficient of friction has no real meaning, but it may rise to 100 or more: it is necessary to prise the surfaces apart with a chisel and the contact has the bulk strength of the metal. It is only when we allow a trace of air, or other contaminant, to enter the apparatus that the friction falls to a reasonable level. This observation that the friction of naked solids is very high makes us realize how fortunate it is that in engineering practice, and, in fact, in many everyday affairs, metals and other surfaces are always contaminated even when we think we have cleaned them thoroughly. If it were not for this, we would find the world a very 'sticky' place to live in, and much of our machinery would come to a sudden and disastrous stop.

Surface Temperature of Sliding Solids

All these experiments are for surfaces which are moving very slowly. What happens if the sliding speed is appreciable? One of the most important differences is that there will be a temperature rise at the surface.

The energy lost during sliding is dissipated mainly in the form of heat, and quite primitive calculations of the amount of heat liberated and of the rate at which it is conducted away suggest that the temperature rise of the surface layers may be high. If we endeavour to measure this by embedding thermometers in the solids near the surface, we find that the rise is very small, but this is mainly because we cannot get close enough to the surface. An obvious method is to use the surfaces themselves as a thermometer. We may make our sliding surfaces of two different metals, and use the rubbing contact itself as a thermocouple. A measurement of the electromotive force generated on sliding them provides a record of the surface temperature.

Such measurements confirm in a very striking way the existence of local high temperatures at the points of contact of the rubbing surfaces. As would be expected, the temperatures reached depend upon the load, the speed of sliding and the heat conductivity of the metals. Also the temperatures fluctuate very rapidly during sliding, and it is necessary to use an instrument of high frequency, such as a cathode ray oscillograph or high-frequency galvanometer, in order to record them. It is found that, with the lower melting metals, we readily reach their melting point, and the temperature does not rise above this.

With metals of high melting points, however, temperatures of the order of 500–1,000° C. are easily reached. These temperatures are confined to the very thin surface layer, and the mass of the metal appears to be quite cool. These very high temperature flashes of 1,000° C. may last only for a few ten-thousandths of a second (Fig. 4).

If we slide non-metals such as wood or glass or diamond, which are bad thermal conductors, we should expect the temperature rise to be still higher. We cannot, of course, use this thermo-electric method to measure the temperature. We may, however, use other means, one of which is a visual method. If polished surfaces of glass or quartz are used, and the apparatus so arranged that a clear image of the rubbing surfaces can be seen, it is found that, if the sliding is carried out in the dark, a number of tiny stars of light appear at the interface between the rubbing surfaces. The points of light are reddish in colour at low speeds, and become whiter and brighter as the speed or the load is increased. It is clear that they correspond to small hot spots on the surface, and their position and distribution over the surface change from instant to instant as the high points in intimate contact move or wear away, and new points come into contact. These hot spots can also be photographed in a very simple way: if a photographic plate is placed on a turntable with the glass side upward and allowed to rotate with a metal slider resting on it, the luminous hot spots developed at the points of rubbing contact will photograph themselves on the emulsion. An alternative, and a valuable method, is to use a lead sulphide cell which is sensitive to flashes of infra-red radiation. With this we have been able to measure the rapid rise and fall in temperature of a single hot spot.

The main point to be emphasized here is how easily local high temperatures are developed. For example, with two non-conductors sliding together, or even with a metal sliding on a non-conductor, the temperature at the local points of contact may exceed 500° C., that is, red hot spots can be formed, although the speed of sliding is only one or two feet per second. These local hot spots are important in a number of physical processes associated with the rubbing of solids. They are, for example, very important in polishing, and there is strong evidence that the formation of the polished, or Beilby, layer on metals and other solids when they are rubbed is due to a localized melting or high-temperature softening of the solid at the points of rubbing contact. They also play an important part in skiing: the low friction of sliding on ice and snow is due in a large measure to a localized surface melting.

Frictional Properties of Plastics

We may gain further insight into the mechanism of friction by considering the behaviour of a group of structurally related plastics (Table 1).

TABLE 1

Polymer	Chemical formula	Coefficient of friction
'Teflon'	$\left[-CF_2-CF_2- \right]_n$	0·04
Polyethylene	$\left[-CH_2-CH_2- \right]_n$	0·1
Polystyrene	$\left[-CH_2-CH(C_6H_5)- \right]_n$	0·5
'Perspex'	$\left[-CH_2-C(CH_3)(COOMe)- \right]_n$	0·8

It will be seen that the friction of the plastics 'Perspex' and polystyrene, which have branching side-chains, is high. Putting it crudely, we may say that the branching side-chains interlock and get in the way, and we cannot easily slide one sheet of molecules over the other. Polyethylene, which is a simple long-chain compound, gives a comparatively low friction, $\mu = 0{\cdot}1$, and sliding can occur more easily. Now let us consider a reasonably new plastic, namely, 'Teflon'. In this, the hydrogen atoms are replaced by fluorine. The fluorine atom is large and has an effective negative charge, so that it will screen the positive charge on the carbon atoms. Slip should occur easily between these negative sheets of fluorine and the friction should be low; the coefficient of friction is indeed very low, $\mu = 0{\cdot}04$, which is comparable with that of ice. It has remarkable frictional properties and even at 300° C. the friction is still very low. It will undoubtedly prove a valuable material. It has, however, certain disadvantages. It is a non-conductor of heat and has a high coefficient of thermal expansion. If we use it as a bearing, it may get hot, expand and stick. We have therefore tried the experiment of incorporating it in a porous metal. We take, say, sintered copper which has a number of fine pores in it and impregnate the surface layers with 'Teflon' (Fig. 5). In this way we have a material which possesses the mechanical properties and thermal conductivity of sintered copper, but, since the surface is always covered with a thin film of 'Teflon', it has the frictional properties of 'Teflon' (Table 2).

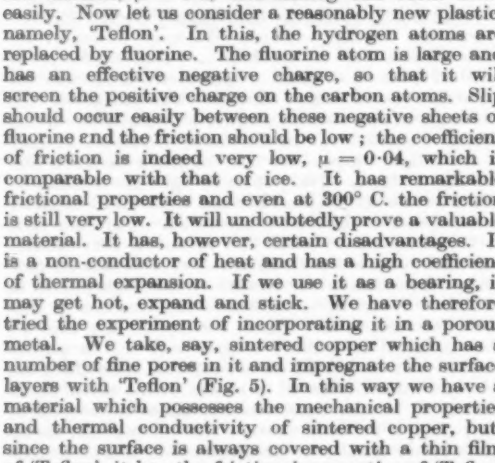


Fig. 5. Section of sintered copper impregnated to a depth of about 1 mm. with 'Teflon'. (*a*) Sintered copper, (*b*) impregnated surface layer. Magnification × 10

TABLE 2

Temperature	Coefficient of friction: Copper	Coefficient of friction: Copper impregnated with 'Teflon'
15° C.	about 1·0	0·05
100° C.	,, ,,	0·05
200° C.	,, ,,	0·05
250° C.	,, ,,	0·05

This value for the coefficient of friction of 0·05 is lower than the boundary friction usually obtained even with very good lubricants. Moreover, the act of sliding does not remove the film, but merely feeds it on to the surface. Such a material should prove a useful bearing or anti-friction material which can be used without any lubricant and which will function at quite high temperatures.

There has been some tendency in the past for us to accept the surface which the engineer gives us, and then try to make it work and to lubricate it. There is something to be said for the alternative of designing a surface which has the right frictional properties and then giving it to the engineer to use.

RESEARCH LABORATORIES OF THE BRITISH ELECTRICITY AUTHORITY

By Dr. J. S. FORREST
Director

THE power stations of the British Electricity Authority have a total capacity of 10 million kW. and generate about 46,000 million kWh. a year; it is evident that there is great scope for research on the operational problems of an industry of this magnitude.

The first opportunity for research on a national basis occurred in the early years of operation of the National Grid system, when it became apparent that a central laboratory was necessary to investigate the high-voltage transmission problems which were then being encountered for the first time in Great Britain. Accordingly, the Central Electricity Board established laboratories at Croydon in 1932–34, and in the following years made plans to build more comprehensive laboratories at Leatherhead, equipped to investigate the diverse electrical and mechanical, physical and chemical, problems which arise in the operation of an extensive transmission system. Owing to the difficulties of the Second World War and the immediate post-war years, however, it was not possible for the Board to start work on the Leatherhead project. With the coming of nationalization of the supply industry (Electricity Act, 1947), the laboratories of the Board became in April 1948 the central laboratories of the British Electricity Authority. Moreover, the 1947 Electricity Act placed considerable emphasis on research, so that the Authority was able to proceed immediately with the construction of the research laboratories at Randall's Farm Lane, Kingston Road, Leatherhead, Surrey. The new building was started in June 1948, and was formally opened this year on July 15 by the Rt. Hon. Lord Citrine, chairman of the Authority.

It is the aim of the Laboratories to contribute to the solution of any of the manifold problems which may arise in the electricity supply industry. Detailed investigations cannot, of course, be made in all parts of such a wide field, and close co-operation is there-

fore maintained with other national bodies, research associations, manufacturers, universities, engineering institutions, professional institutes and scientific societies.

The nature of the scientific work of the Laboratories may best be indicated by summarizing some of the investigations which have been undertaken or are now in progress. When 132-kV. overhead lines and substations were first put into operation in industrial areas, difficulties were experienced due to the flashover of insulators in fog, and research was initiated with a view to solving this problem. The immediate object of this work was to devise a method of measuring the performance of insulators operating in these conditions; the best available type could then be employed, and improved designs could be developed. This work next led to a study of the electrical properties of aqueous films on porcelain surfaces and then to the elucidation of the mechanism of insulator flashover in humid and polluted atmospheres. Furthermore, it was found that the reliability and efficiency of high-voltage insulators could be increased if the voltage distribution were controlled in such a way as to prevent excessive voltage gradients or spark discharges. One method of achieving this is to glaze the porcelain insulators with a glaze having the required resistance, and this led to the development by an English manufacturer of a semi-conducting ceramic glaze. Semi-conducting glaze consists essentially of a mixture of metallic oxides incorporated in a glassy matrix; this material has an interesting structure, and work is at present in progress on its electrical characteristics and on the contact phenomena between the glaze and a metal or cement electrode.

Certain aspects of insulating liquids are also being investigated. For example, a D.C. conductivity test has been devised for controlling the condition of hydrocarbon oils used in transformers and switchgear. In this connexion, the mechanism of conductivity in insulating oil containing very small quantities of free water is being studied. Experimental investigations are also being made on the oxidation of oil and on the interfacial tension at an oil-water interface.

An important programme of research on high-voltage transmission has been started recently. An experimental transmission line, 800 yards long, has been built for this work, and is at present being operated at 250–300 kV. Measurements are being made of the power loss due to corona discharge and insulator leakage in various weather conditions. The intensity of the radio interfering field from this line is also being measured, and comparisons are being made of the signal/noise ratio for amplitude-modulation and frequency-modulation transmissions. Interference with television reception is being studied, and it has been found that good reception can be obtained with the television aerial only ten yards from the line conductors.

About forty per cent of the breakdowns on the overhead lines of the National Grid system are due to lightning, and much attention has therefore been directed to methods of improving the performance of power systems when subjected to high surge voltages. Three lines of investigation are at present being followed: in the first place, the electric strength of insulating materials and power system plant is being studied under impulse conditions—the new 1,400-kV. surge generator at Leatherhead will be of assistance in obtaining experimental data in this wide field; secondly, radio methods are being used to give the control engineers objective information about the occurrence of thunderstorms in the areas under their control; and finally, the records of system breakdowns due to lightning are being examined statistically. It is noteworthy that a recent analysis of breakdown records for fourteen years gives a reliable picture of the seasonal and diurnal variations in thunderstorm severity and of the fluctuations from year to year.

About twenty thousand miles of steel-cored aluminium conductor is in use on the Grid lines, and development work is continually in progress on methods of jointing and protection against corrosion in industrial and coastal atmospheres. Samples of conductor from various parts of Great Britain are examined, and an interesting result of this work is that pure aluminium has been found to corrode progressively—the commonly accepted view that a protective layer is formed which prevents further attack is erroneous.

Other transmission problems which are being studied are conductor vibration, earthing, deionization of arcs, radio and inductive interference, harmonics, and the measurement of noise from transformers and air-blast switchgear.

As the new Laboratories have grown from the transmission background of the Central Electricity Board, it is only to be expected that most of the work should be devoted to electric power transmission. The scope of the work is now being extended to cover generation and distribution more adequately. For example, investigations have been made to develop methods of reducing the precipitation of moisture from generating-plant water-cooling towers. This apparently mundane problem has led to interesting experiments with a model cooling tower and to a study of the physical and meteorological phenomena relating to water droplets. The results obtained may then suggest possible ways of improving cooling-tower efficiency. Thus, as frequently happens, an operational trouble leads to testing and development, then to 'pure' research, and finally, through 'applied' research, back to normal practice.

OBITUARY

Dr. G. A. Waterhouse

GUSTAVUS ATHOL WATERHOUSE, who died on July 29, took a prominent part in the development of natural history in New South Wales over a period of more than forty years. He was born at Waverley, Sydney, on May 21, 1877, and was educated at Sydney Grammar School and the University of Sydney. He graduated B.Sc. in 1899 and B.E. in 1900. After graduation he was appointed to the assay staff at the Sydney branch of the Royal Mint and remained there until the Mint was closed in 1926, when he retired. In 1924 he obtained the degree of D.Sc. at the University of Sydney for his work on the hybridization of butterflies.

Waterhouse made important contributions to science in Australia in two ways: first, by his researches on Australian butterflies and, secondly, by his activities in connexion with the advancement and administration of scientific societies and institutions. His collection of butterflies which ultimately became the finest existing collection of Australian species

was commenced in 1893 while he was still at school. It is now preserved in the Australian Museum, to which he presented it about fifteen years ago.

Waterhouse took an active part in the Australian societies interested in science in general and natural history in particular, and most of them he served in an executive capacity at some time. The Royal Entomological Society of London conferred on him the unusual distinction of Honorary Life Fellowship. He was honorary entomologist of the Australian Museum from 1919; an elective trustee from 1926 until his resignation in 1947 on account of ill-health; and president of the Board of Trustees in 1930.

For any ordinary man it might be expected that an absorbing interest in Lepidoptera and intense activity in scientific societies would occupy all the leisure time available. But Waterhouse was remarkably active, both physically and mentally, and always had some interests in addition to those mentioned. About 1900 he was interested in the distribution of basic volcanic dykes in the Triassic Hawkesbury Sandstone Series in the Sydney district; for many years he collected Mollusca, of which his mother presented a fine collection to the Australian Museum; and he was a keen philatelist. He is survived by his widow, two sons and two daughters; one son was killed on active service in New Guinea during the Second World War. A. B. WALKOM

NEWS and VIEWS

Civil Engineering at Liverpool:

Prof. R. G. Batson

PROF. R. G. BATSON retires at the end of September from the John William Hughes chair of civil engineering in the University of Liverpool. After leaving King's College, London, he received practical training at Woolwich Arsenal. In 1908 he went to the National Physical Laboratory and was one of a team of five members in the Engineering Department at that time. For some years he carried out research of a mechanical engineering nature, but later became a principal scientific officer on road research and was in charge of the Road Research Board. He was appointed to the chair of civil engineering in the University of Liverpool in 1936, and since that time he has directed the teaching of that branch of engineering in an energetic, enterprising and sympathetic manner. He has introduced new courses of lectures, and his success may be gauged by the readiness with which his students secure satisfactory appointments. During his tenure of the chair, Prof. Batson has been dean of the faculty of engineering for a continuous period of ten years. The holder of a number of awards for original papers, Prof. Batson is also the joint author of a well-known book on "Mechanical Testing" and has recently published a book on "Roads".

Dr. J. B. B. Owen

DR. J. B. B. OWEN, who succeeds Prof. R. G. Batson on October 1 at Liverpool, is thirty-nine years of age and obtained a first-class honours degree in civil engineering in 1931 at University College, Cardiff. He was awarded the Meyricke Scholarship to Jesus College, Oxford, in 1931, where he studied for two years in the Engineering Laboratory and graduated as B.Sc. (Oxford) for research on "Problems of Stress Distribution in Frameworks". He obtained his doctorate (D.Sc.) at Oxford this year. After leaving Oxford in 1933, Dr. Owen was engineering scientific assistant for two years at the British Cotton Industry Research Association, where he was employed on the development of machinery for opening and cleaning cotton, and afterwards for one year in the Design and Stress Office of Messrs. A. V. Roe, Manchester, on the development of autogyros and aeroplanes. Dr. Owen spent twelve years, 1936–48, on the scientific staff of the Royal Aircraft Establishment, where his main duties consisted of research on aircraft structures and instruction of staff investigating aircraft accidents, airworthiness, and full-scale structural research in flight and landing. Most of Dr. Owen's work while at the Royal Aircraft Establishment has been published as *R.A.E. Reports* or as *Reports and Memoranda* of the Aeronautical Research Committee.

American Geographical Society Awards

THE following awards have been announced by the American Geographical Society: Cullum Geographical Medal, to Dr. H. W. Ahlmann, professor of geography in the University of Stockholm, for inspiring "international cooperation in world-wide glacier study"; Charles P. Daly Medal, to Prof. L. Dudley Stamp, professor of social geography in the London School of Economics and Political Science, University of London, and adviser on rural land utilization to the Ministry of Agriculture, for "contributing much to the increase of food production in Britain and for a leading part in recent efforts at town and rural planning for optimum use of the land"; David Livingstone Centenary Medal, to Prof. R. L. Pendleton, principal soil technologist, Office of Foreign Agriculture, U.S. Department of Agriculture, "as one of the world's leading experts in soil survey and classification".

Air Conditioning and New Lighting at the National Gallery, London

AIR-CONDITIONING plant and modern artificial lighting have recently been installed by the Ministry of Works in a gallery of the National Gallery, Trafalgar Square, London, W.C.2, and the public was admitted on August 21. This installation puts the National Gallery among the most advanced of its kind in Europe. During the Second World War, when the national collections were stored in Manod Quarry in a constant air-conditioned atmosphere (see *Nature*, 151, 123; 1943), the absence of the fluctuations in relative humidity which normally occur in the London climate reduced damage to the pictures by 75 per cent (this damage is more marked for pictures painted on wood rather than canvas). The experience of the War years led to the Weaver Report in 1947, when it was urgently recommended that air-conditioning plant should be built for

preserving the national treasures in an atmosphere of constant temperature and relative humidity. Since the air is cleaned by the new plant, the pictures do not need glass fronts to protect them from dirt, and this helps the lighting in that problems of reflexion are eliminated. As regards the lighting itself, the gallery has a ceiling of special glass which does not alter the colour of the daylight filtering through. The artificial illumination is made up of both fluorescent tube lighting and filament lamps, which together produce a natural light of 15–20 ft.-candles in intensity. The air-conditioning machinery, which cost £15,000 together with building costs of £25,000, is large enough to serve a number of other rooms, and it is hoped to equip other parts of the National Gallery with this system in the future. The plant provides a temperature of 65° F. with air at 68 per cent relative humidity throughout the year; extreme winter and summer air conditions of, respectively, 30° F. at 78 per cent humidity and 80° F. at 58 per cent humidity, have been allowed for. The air enters through ceiling ducts and leaves by grilles at floor level, and it is treated at the rate of six complete changes an hour.

Fertility and Sterility

Fertility and Sterility, of which the first number was published in January (1, No. 1; pp. 99; New York: Paul B. Hoeber, Inc., Publishers, 49 East 33rd Street, New York 16; 8 dollars or 9.50 dollars a year) is the official journal of the American Society for the Study of Sterility. The general purpose of this new publication is to assemble in one place accounts of original investigations, reports of clinical experiences, review articles and correspondence pertinent to the subject of infertility. The more immediate purpose is to assist clinicians in the treatment of human infertility. In the past, information required by the clinical investigator or practitioner was scattered in papers in a wide range of periodicals, and from this point of view the appearance of the new periodical will be of substantial value to those interested in the problems of fertility and sterility. The Editorial Board of the new journal consists of physicians, and the articles which appear in the three issues published up to now are confined mainly to medical aspects of fertility and sterility in man. It seems, however, and is very much to be hoped, that the Editorial Committee will encourage contributions from outside the medical circle, particularly from research workers concerned with the basic sciences of anatomy, biology, embryology, genetics, physiology and veterinary medicine, who at present lead in most major developments in the field of fertility and sterility. Provided that such enlightened editorial policy is introduced and maintained, there is little doubt about the successful future of *Fertility and Sterility*.

Universal Congress of Esperanto

THE thirty-fifth Universal Congress of Esperanto was held at the Sorbonne in Paris during August 5–12, when more than two thousand members of about thirty nationalities took part. The Science Section of the Congress welcomed the initiative of a number of Japanese men of science in commencing to publish their work in Esperanto and appealed to other men of science, particularly those using the less widely understood languages, to follow their example. The Section also undertook, in collaboration with the Universal Esperanto Association and the International Scientific Esperanto Association, to ask leading men of science to name the text-books and other works in their respective fields which it would be most profitable to translate into Esperanto. This decision followed from a proposal in similar terms recently made by Prof. Lavergne, of the Faculty of Law at the Sorbonne. The Section also resolved, in conjunction with the International Scientific Esperanto Association and the Academy of Esperanto, on measures to be taken further to develop and standardize Esperanto technical vocabularies.

Foot-and-Mouth Disease Research

THE work at the Foot-and-Mouth Disease Research Station has up to the present been conducted under the scientific direction of a committee appointed by the Minister of Agriculture, with the financial and administrative arrangements being made by the Ministry. The Station is now to join the group of research institutes being financed by a grant-aid from the Ministry of Agriculture and coming under the scientific supervision of the Agricultural Research Council. The new governing body is being constituted by the Minister of Agriculture and the Secretary of State for Scotland, in agreement with the Agricultural and Medical Research Councils. The membership of the governing body is as follows: Sir Alan Drury (*chairman*), Dr. C. H. Andrewes, Prof. S. P. Bedson, Mr. T. Dalling, Prof. R. E. Glover, Dr. J. Russell Greig, Prof. Wilson Smith and Prof. W. I. B. Beveridge.

Royal Society of Arts: 1951 Centenary Prize

THE Royal Society of Arts is offering a 1951 prize of a gold medal and a sum of £500 for the best proposal submitted on "A Means of Promoting the Production or the Economic Utilization of Food in Great Britain". The proposal may be quite general or may be concerned with any particular branch or aspect of food production. The Society has instituted this prize as a part of its celebrations of the centenary of the Great Exhibition of 1851, which it originated, and as a revival of the policy of offering prizes for inventions and other projects, which the Society employed in the early days of its existence. Entries, which may be submitted by British subjects, citizens of the Commonwealth and the Irish Republic, and foreigners permanently resident in the United Kingdom, must reach the Secretary, Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, by March 1, 1951.

Congress on Building Research, 1951

A COMPREHENSIVE congress on building research, to be held in London during September 11–20, 1951, will mark the rapid developments in building science made since the end of the Second World War, and has been arranged because of the great and growing interest shown in the subject in many countries. The congress is sponsored by the British professional institutions and learned societies interested in building science, and by government departments, with the support of representative industrial federations in Great Britain. The Department of Scientific and Industrial Research is providing the central organisation. Papers are being invited from research workers in many countries on a wide range of topics, and arrangements are being made to welcome to the congress a large number of visitors from overseas.

The purpose of the congress will be to review the progress made in research in relation to architecture, building and the associated branches of civil engineering, and a large number of topics will be discussed. The programme will be organised in three divisions, which will hold concurrent meetings; visits to buildings of interest and to civil engineering works, etc., will also be arranged. Further details can be obtained from the Organising Secretary, Building Research Congress 1951, Building Research Station, Bucknalls Lane, Garston, Watford, Herts.

Fresnel Diffraction Pattern and the Electron Microscope

MR. M. E. HAINE, of the Associated Electrical Industries Research Laboratory, Aldermaston, writes that his attention has recently been directed to the report on the "Conference on Electron Microscopy, Delft", published in *Nature* of September 17, 1949, p. 481. In the first column on p. 482 Mr. Haine is reported as suggesting the use of the Fresnel diffraction pattern from a half plane as a test object for the determination of resolution in the electron microscope. He wishes to say that, in fact, he went to some pains in his paper to point out the fallacy in such a test. In his suggestion for the use of a half plane as a test object, Mr. Haine declared that it is only suitable for conditions of incoherent illumination, and went on to explain the complications arising when any degree of coherence is introduced.

The Night Sky in September

NEW moon occurs on September 12d. 03h. 29m. U.T., and full moon on Sept. 26d. 04h. 21m. The following conjunctions with the moon take place: Sept. 10d. 20h., Venus 1° S.; Sept. 16d. 17h., Mars 3° N.; Sept. 23d. 13h., Jupiter 1° N. In addition to these conjunctions with the moon, the following other conjunctions occur: Sept. 9d. 04h., Venus with Regulus, Venus 0·7° N.; Sept. 24d. 03h., Mercury with Venus, Mercury 2·6° S.; and Sept. 29d. 22h., Venus with Saturn, Venus 0·6° S. Mercury is an evening star during the earlier part of the month, setting at 19h. on Sept. 1, but is too close to the sun to be observed. On Sept. 17 the planet is in inferior conjunction and at the end of the month rises 1½ hours before the sun. Venus is a morning star, the times of rising being 3h. 25m., 4h. 05m. and 4h. 55m. on Sept. 1, 15 and 30, respectively, and can be seen in the morning hours, stellar magnitude −3·3. Mars can be seen for a short period in the evening, setting at 20h. 35m., 20h. and 19h. 30m. at the beginning, middle and end of the month, respectively. Jupiter is visible throughout the night, setting in the morning hours at 4h. 30m. on Sept. 1, and 2h. 20m. on Sept. 30. Saturn, in conjunction with the sun on Sept. 16, is not favourably placed for observation until the end of the month, when it is a morning star, rising more than an hour before sunrise, and can then be seen for a short time in the eastern sky. Occultations of stars brighter than magnitude 6 are as follows: Sept. 30d. 20h. 31·1m., 27 Taur. *m.* (*D*); Sept. 30d. 21h. 26·3m., 27 Taur. *m.* (*R*); Sept. 30d. 21h. 26·7m., 28 Taur. (*R*). *R* and *D* refer to reappearance and disappearance, respectively, and the latitude of Greenwich is assumed. A total eclipse of the sun, invisible at Greenwich, occurs on Sept. 12. The central line runs from lat. 85° 10′ N., long. 66° 42′ E., to lat. 34° 23′ N., long. 154° 35′ E. The circumstances of the eclipse are:

Eclipse begins	Sept. 12d.	01h.	23·2m.
Central eclipse begins	12	02	50·1
Central eclipse ends	12	04	27·0
Eclipse ends	12	05	53·6

A total eclipse of the moon, partly visible at Greenwich, takes place on Sept. 26, the circumstances being:

Moon enters penumbra	Sept. 26d.	01h.	20·0m.
,, ,, umbra	26	02	31·5
Total eclipse begins	26	03	53·8
Middle of the eclipse	26	04	16·7
Total eclipse ends	26	04	39·6
Moon leaves umbra	26	06	01·9
,, ,, penumbra	26	07	13·5

Vernal equinox is on Sept. 23d. 15h.

Announcements

THE College of Physicians of Philadelphia has awarded the Alvarenga Prize for 1950 to Dr. Ephraim Shorr, associate professor of medicine, Cornell University Medical College, for his outstanding work on the mechanism of shock. The Alvarenga Prize was established by the will of P. F. DaC. Alvarenga, of Lisbon, Portugal, an associate fellow of the College of Physicians of Philadelphia, to be awarded annually by the College on the anniversary of his death on July 14, 1883.

A CONFERENCE on differential anthropology has been organised by the Société de Morpho-physiologie humaine and will be held at the Abbaye de Royaumont (near Paris) during September 11–16. The programme of the conference will be devoted to the study of the morphological, physiological and psychological aspects of the differentiation of individuals, and a number of participants from countries other than France will be contributing papers. Further details can be obtained from the secretary-general of the conference, Dr. P. Mabille, 34 rue Raynouard, Paris 16e.

THE Research Fund of the Chemical Society provides grants for the assistance of research in all branches of chemistry. About seven hundred pounds a year is available for this purpose, the income being derived from a donation of the Worshipful Company of Goldsmiths, from the Perkin Memorial Fund, and from other sources. Application forms, obtainable from the General Secretary, Chemical Society, Burlington House, Piccadilly, London, W.1, should be submitted not later than November 1. Applications from Fellows of the Society will receive prior consideration.

THE premises of the headquarters of the British Scientific Instrument Research Association, 17 Princes Gate, London, S.W.7, have been acquired by the Government of Ethiopia for its Legation and must be vacated by the end of August. Consequently, it has been decided to move the information department and the library of the Association immediately to the Association's laboratories at 'Sira', Southill, Elmstead Woods, Chislehurst, Kent. Temporary accommodation will be provided in an existing bungalow within the grounds of the laboratories; but it is hoped that a new building, for which plans have already been approved, will be erected and completed by the summer of 1951. The bungalow will then form an annexe to the library and will provide valuable storage space for many years to come. New headquarters in London for the director and administrative staff are being sought.

COINCIDENCES BETWEEN PROTONS AND GAMMA-RAYS IN (*d*,*p*) REACTIONS

By C. D. CURLING and J. O. NEWTON
Cavendish Laboratory, Cambridge

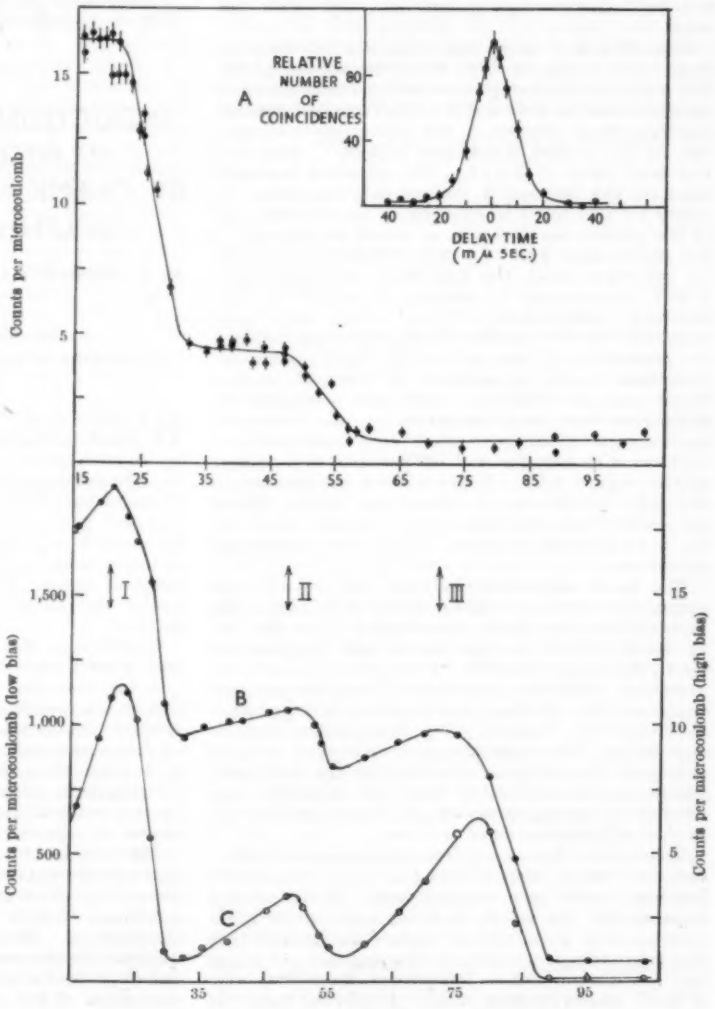
A COINCIDENCE circuit with a resolving time of 15 millimicroseconds has been employed to study the simultaneous emission of protons and gamma-rays from light nuclei under deuteron bombardment, using scintillation counters and photomultipliers (E.M.I. Type 5032). Naphthalene loaded with 1 per cent anthracene gave a high gamma-ray detection efficiency and a low sensitivity to neutrons. The protons were detected by a thin transparent layer of pure anthracene (~ 3 mgm. cm.$^{-2}$) obtained from the surface of a hot saturated solution in amyl acetate by cooling; the anthracene was first purified by four distillations with ethylene glycol.

Two coincidence units, each using a germanium diode and a shorted coaxial line to define the resolving time, were fed through 72-ohm coaxial lines from pulse limiters attached directly to each multiplier. The relative delay of the pulses could be altered by changing the lengths of these lines; a typical result is shown in Fig. *A*. One unit fed from the collectors of the multipliers, had zero relative delay and measured both real and random coincidences, while the other with a delay of 70 millimicroseconds was fed from the last dynodes and measured only the random counts. This simultaneous measurement of real and random counts avoided errors caused by fluctuations in the intensity of the deuteron beam.

The target was mounted in a thin copper wave-guide (2·7 cm. × 1·5 cm.) and the deuteron beam collimated by two molybdenum foil diaphragms of 1 cm. diameter. The detectors were mounted opposite each other at 90° to the beam. The solid angle in steradians subtended at the target by the proton detector was 0·48, and by the gamma-detector 1·9 and 0·68 during the proton-range and gamma-absorption measurements respectively.

The following results were obtained using a deuteron energy of 430 keV.

$Li^6(dp)Li^7$. A plot of the proton counts against absorber thickness gave an extrapolated range of 29·5 cm. for the long-range group, the two groups not being resolved. A similar plot of coincidence



Range in air (cm.)

Numbers-range curves for protons emitted in the bombardment of boron-10 by 430-keV. deuterons under identical geometrical conditions
A. Proton – gamma-ray coincidences.
B. Protons at low bias.
C. Protons at high bias.
The real-to-random ratio at I = 4·2; at II = 2·3.

Inset. Resolution curve of the coincidence circuit for boron-10 proton – gamma-ray coincidences (330-keV. deuterons) not corrected for random counts

counts gave a range of 25·2 cm., as would be expected if the gamma-rays were associated with the short-range group. A lithium-6 target (7·6 μgm. cm.$^{-2}$) was used and gave a maximum of 3·25 coincidences per microcoulomb with a real-to-random ratio of unity and less than 0·15 background coincidences per microcoulomb beyond the long-range group.

A lead absorption measurement on the coincident gamma-rays gave 510 ± 25 keV. for their energy, in agreement with the energy difference of the proton groups measured by Buechner *et al.*[1].

$B^{10}(dp)B^{11}$. Similar results were obtained from the bombardments of natural boron and of boron-10, and those from the separated isotope target are given in the graph. As expected, the measurements show that gamma-rays are to be associated with the two shorter-range groups and not with the third.

Figs. *B* and *C* show that there are 3·5 times as many protons in the first as in the second group. The emission of these protons leaves boron nuclei in excited states[2] at 4·47 and 2·15 MeV., and, if gamma-radiation leads directly to the ground-state in each case, it will consist of 4·47 and 2·15 MeV. quanta in the same ratio of 3·5 : 1. The observed intensity ratio for the coincident gamma-radiation (Fig. *A*) was 3·4; this could be changed by altering the gain of the gamma-ray detector, as would be expected if the gamma-rays were of widely different energy. If, on the other hand, the 4·47-MeV. level emits two 2-MeV. gamma-rays in cascade, a ratio of 7, substantially independent of gain, would have been obtained. It follows that the shorter-range protons are predominantly associated with single gamma-ray transitions to the ground-state of boron-11, as was found also by Thirion[3]. This was confirmed by absorption measurements taken on the coincident gamma-rays which gave absorption coefficients of 0·34 cm.$^{-1}$ in lead for each of the first two groups, and in copper 0·15 ± 0·05 cm.$^{-1}$ for the first group and 0·25 ± 0·04 cm.$^{-1}$ for the second group. These are lower than the theoretical values given by Heitler[4], probably because of the poor geometrical conditions.

The good agreement between the proton and gamma-ray intensity ratios shows that, under the experimental conditions, the smaller pulse-size due to the 2·15-MeV. gamma-quanta was compensated for by the larger Compton cross-section, so that the detection efficiency was about equal for the two energies. The efficiency was found to be 7 per cent, assuming the absence of proton-gamma angular correlation. This corresponds to detection of practically all the Compton electrons for the 4·47-MeV. gamma-ray as calculated from the Klein–Nishina formula for the thickness (2 cm.) of the anthracene-loaded naphthalene used.

Coincidences between protons and gamma-radiation have previously been observed in (α,p) reactions[5,6], but with rather slow counting-rates. In the present experiments, the small resolving time of 15 millimicroseconds permitted a high disintegration-rate and hence a high coincidence counting-rate (~ 20 per sec. for lithium, and ~ 100 per sec. for boron) with a good real-to-random ratio. Resolving times as short as 5 millimicroseconds could probably be obtained[7], but this may be near the limit[8] set by the photomultiplier. However, the present technique offers good prospects for a much more detailed study of the properties of the gamma-radiation emitted in (dp) reactions.

We wish to thank Dr. W. E. Burcham for advice and encouragement throughout this work. We are grateful to Sir John Cockcroft and the Atomic Energy Research Establishment Harwell, for assistance; Dr. W. D. Allen's group provided the separated targets, and Mr. E. H. Cooke-Yarborough advised us on the design of coincidence circuits of small resolving time. [May 24.

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INDUCTION OF MUTATION IN *MICROCOCCUS PYOGENES* BY CHEMICAL INACTIVATION OF SULPHHYDRYL GROUPS

By J. BENNETT CLARK, Prof. ORVILLE WYSS
AND
Dr. WILSON S. STONE
Laboratories of Bacteriology and Genetics, University of Texas, Austin

BARRON *et al.*[1,2] reported that the first point of attack in enzyme systems which were irradiated by X-rays, alpha-rays, beta-rays and gamma-rays was the sulphhydryl groups of the enzyme proteins. If inhibition of the sulphhydryl-containing enzymes was only partial, reactivation could be accomplished by addition of glutathione. The emphasis on peroxide in recent work on mutagenic action suggests that one point of attack of radiations in inducing mutation might also be at sulphhydryl groups of the gene protein.

Colwell and McCall[3] found that the antibacterial and antifungal activity of 2-methyl, 1-4 naphthaquinone was due to the blocking of sulphhydryl groups on enzymes or metabolites essential for growth. Stable small colony variants of four strains of *Escherichia coli* were produced in large numbers in a synthetic medium containing this vitamin K homologue in sublethal concentrations[4]. The affinity of this naphthaquinone for —SH groups is well known in organic chemistry[5].

The purpose of this work was to determine whether this naphthaquinone could induce antibiotic-resistant mutants in *Micrococcus pyogenes* var. *aureus*, and to determine if such mutagenicity was due to —SH inactivation. Menadione (2-methyl, 1-4 naphthaquinone, Merck) was dissolved in 80 per cent acetone (which yielded a sterile solution) to give a final concentration of 0·3 per cent, then added to nutrient broth in amounts sufficient to give the desired final concentrations. Aliquots of the menadione-treated nutrient broth were allowed to stand at room temperature for one hour prior to inoculation with 0·1 ml. of a log-phase culture of *Micrococcus pyogenes* var. *aureus*, *FDA* strain 209. After 18 hr. incubation

Table 1. Effect of Various Concentrations of Menadione on the Incidence of Mutants in *Micrococcus pyogenes*

Addition to medium	Penicillin-resistant*	Streptomycin-resistant*
Untreated control	1·0	1·0
Acetone, 3%	1·4	1·3
Menadione, 12 p.p.m.	no growth	no growth
" 6 "	21·0	4·6
" 3 "	8·2	3·2
" 1 "	3·0	2·1
" 0·5 "	1·8	1·6

* Results expressed as relative numbers of mutants per million cells with controls taken as unity.

the resulting cultures were assayed for penicillin and streptomycin-resistant mutants by the method of Stone *et al.*[6].

Table 1 shows the effects of various concentrations of menadione in increasing the numbers of drug-resistant organisms in the population. The acetone control shows that the result was actually due to the menadione and not to the solvent. Both streptomycin and penicillin-resistant colonies were isolated and found to retain their resistance after repeated transfer on plain nutrient agar. Further tests showed that the increase in mutants occurred soon after inoculation, indicating that the selective action of the environment was not a major factor in their appearance. Another factor which aids in ruling out selection is the number of different mutations which this compound has been found to induce. Besides mutations to penicillin and streptomycin resistance, menadione also induces small colony variants in *E. coli*[4], and induces mutation of *M. pyogenes* towards inability to ferment mannitol[7]. It is unreasonable to assume that the same selective factors should be operative in each case.

Table 2. Action of Cysteine in Inactivating the Mutagenicity of Menadione in *Micrococcus pyogenes*

Addition to medium	Penicillin-resistant*
Untreated control	1·0
Menadione, 6 p.p.m.	7·7
Menadione + cysteine	2·2
Cysteine added to substrate prior to addition of menadione	5·0
Cells grown in presence of menadione five hours, then cysteine added	7·0
Cells grown in presence of cysteine five hours, then menadione added	1·5

* Results expressed as relative numbers of mutants per million cells with controls taken as unity.

To test for the possibility of this mutagenicity being the result of the inactivation of sulphhydryl groups, cysteine, in a ten-molar excess, was utilized as a source of —SH groups. As shown in Table 2, if cysteine is allowed to react with the menadione and the resulting compound is added to the substrate prior to inoculation, the major part of the mutagenicity is lost. Glycine failed to exert a similar action, indicating that the inactivation was not due to the amino-group. If cysteine is added to the substrate prior to the addition of the menadione, little of the mutagenic effect is lost. Possibly in these circumstances the cysteine competes with other components of the substrate for reaction with the menadione; if the menadione reacts with the cysteine it is inactivated, but, if it reacts with some other component of the substrate, the resulting compound either induces the mutation or protects the menadione from the inactivation by the cysteine, yet still allows it to react directly with more reactive groups in the gene complex. If *M. pyogenes* cells are grown in the presence of menadione for five hours before the addition of the cysteine, there is little or no interference with the mutagenic action. However, if the cells are grown in the presence of cysteine for five hours before the addition of menadione, the major part of the mutagenicity is lost. Possibly in the latter case the cells become saturated with such an excess of —SH groups that the menadione has no appreciable effect.

Other compounds containing sulphhydryl groups, such as methionine, glutathione and sodium thioglycollate, were tested and were found to interfere with mutagenic activity of menadione.

Fildes[8] demonstrated that the antibacterial action of mercury and its salts could be ascribed at least in part to its interference with —SH groups. This same action probably applies also to copper and silver salts. In consideration of this action, sub-lethal concentrations of mercury, silver and copper salts were added to nutrient broth aliquots, which were then inoculated with *M. pyogenes*, and the resulting cultures assayed for antibiotic-resistant mutants.

Table 3. Effect of 'Heavy Metal' Salts on the Incidence of Mutants in *Micrococcus pyogenes*

Addition to medium	Concentration	Penicillin-resistant	Streptomycin-resistant*
Untreated control	—	1·0	1·0
Mercuric chloride	0·1 p.p.m.	1·2	1·6
Merthiolate	0·0005 p.p.m.	0·6	0·8
Copper sulphate	0·01 p.p.m.	0·5	0·8
Silver nitrate	0·01 p.p.m.	0·3	0·7

* Results expressed as relative numbers of mutants per million cells with controls taken as unity.

As shown in Table 3, none of these compounds exhibited any mutagenicity. The slight increase of mutants in the culture treated with mercuric chloride is within experimental error. On the basis of these results, it seems that the mutagenicity of menadione is not due to a mere inactivation of sulphhydryl groups, but it is somewhat more complex. Possibly a matter of accessibility is involved. A biological compound such as a vitamin K homologue might have more free movement within a cell than a foreign metallic ion, and thus might be able to react with genetic material which is fairly well protected within the cell. Or if the heavy metal reacts with such material, the reaction may be more drastic and cause death of the cell rather than the induction of a viable mutant. The significance of the reduction in the incidence of spontaneous mutation by the action of the 'heavy metals' is unknown; in this case a possible selective action by these metals has not been ruled out. Also it is still not determined whether the —SH block exhibited by the menadione is in the protein component of the nucleoprotein or in some enzyme which is essential to gene duplication.

The fact that compounds may react with the same groups in the cell but yield different effects on non-specific mutations suggests that this approach eventually may lead to a procedure for securing specificity in mutagenic action.

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USE OF *ASPERGILLUS NIGER* AS A TEST ORGANISM FOR DETERMINING MOLYBDENUM AVAILABLE IN SOILS TO CROP PLANTS

By Dr. D. J. D. NICHOLAS and A. H. FIELDING

University of Bristol Research Station, Long Ashton, Bristol

IT is known that, in addition to the macronutrients nitrogen, phosphorus, potassium, magnesium and sulphur, the micronutrients iron, zinc, copper, molybdenum, manganese and possibly gallium and vanadium are essential for the normal growth and metabolism of *Aspergillus niger*[1–8]. The fungus has been used by Smit and Mulder as a test organism to study the magnesium and copper status of Dutch soils[9]. Mulder[2,3] has also used the bio-assay method to determine molybdenum-levels in soils; but deficiency values were not recorded.

We have recently determined deficiency levels of molybdenum in British soils where cauliflower (*Brassica oleracea*) showed 'whiptail' effects. This disorder in the Brassica family appears to be due to a deficiency of molybdenum, although other factors may be contributory[10–12]. Davies[13] and Waring *et al.*[14] have reported a correction of 'whiptail' in cauliflower in New Zealand and Australia respectively, by applying sodium or ammonium molybdate to the soil. More recently, Jones[15] and Plant[16] have confirmed these responses in instances of 'whiptail' in Britain.

Aspergillus niger (M.), kindly supplied by Dr. E. G. Mulder, Gröningen, was used in this study. The basal culture solution used has the following constitution:

Dextrose	50 gm.	$FeCl_3.6H_2O$	3 mgm.
KNO_3	5 gm.	$MnSO_4.4H_2O$	0·3 mgm.
KH_2PO_4	0·6 gm.	$ZnSO_4.7H_2O$	2·0 mgm.
$MgSO_4.7H_2O$	0·6 gm.	$CuSO_4.5H_2O$	0·6 mgm.
$CaSO_4.2H_2O$	0·5 gm.	$Ga(NO_3)_3.8H_2O$	0·2 mgm.
		$Co(NO_3)_2.6H_2O$	0·10 mgm.
		$Ni(NO_3)_2.2H_2O$	0·08 mgm.

The above salts are contained in a litre of water distilled from a copper still and then twice from 'Pyrex' glass.

To produce molybdenum-deficiency effects in *Aspergillus niger*, Steinberg[4–6] and Mulder[2,3] used mineral nutrients which were spectrographically free from the micronutrient. Our method, which involves a chemical purification of the inorganic macronutrients and dextrose that comprise the culture solution, is as follows. The mineral macronutrients and dextrose are dissolved in 200 ml. of glass-distilled water, and sufficient 2 *N* hydrochloric acid (redistilled) is added to adjust the *p*H of the culture solution to 3·0. 1 ml. of a 5 per cent solution of copper sulphate and lead nitrate respectively are added, as well as 10 μgm. molybdenum as sodium molybdate, and hydrogen sulphide passed through the solution for 15 min. The colloidal molybdenum sulphide is co-precipitated with the other metallic sulphides. The precipitate is allowed to stand for a few hours and then filtered through an acid-washed No. 42 Whatman paper into a 1-litre 'Pyrex' conical flask. The hydrogen sulphide is eliminated from the solution by boiling, and lead acetate paper is used to confirm its complete removal. After cooling, the micronutrients (except molybdenum), which have been recrystallized twice from glass-distilled water using redistilled alcohol to enhance yields, are added. The culture solution is then made up to 950 ml., adjusted to exactly *p*H2 using redistilled 2 *N* hydrochloric acid, and finally made up to a litre, using glass-distilled water. 50-ml. portions of solution are poured into 1-litre 'Pyrex' conical flasks or 6-in. Petri dishes, which have been thoroughly cleaned with acid and finally rinsed with glass-distilled water.

Another effective method of removing molybdenum is a modification of that proposed by Waring and Werkman for iron[17]. 5 ml. of 2 per cent solution of 8-hydroxyquinoline in 2 *N* acetic acid is added to a solution of the macronutrients and dextrose (100 ml.) at *p*H 5·5 in the presence of 10 mgm. iron and incubated at 35° C. for 24 hr. The solution is filtered through a No. 50 Whatman paper, and redistilled ether is used for removing excess 8-hydroxyquinoline. The ether is eliminated from solution at 80° C. Using either method, the dry weights of mycelia from cultures omitting molybdenum, using 50-ml. portions, varied from 27 mgm. to 89 mgm. The addition of a range of other metals at 0·05 μgm. per 50 ml. culture solution did not appear to affect the growth curve, thus indicating the specificity of the response to molybdenum.

For soils tests the following standard series for molybdenum is used: 0·5, 1, 5, 10, 20, 30, 40, 50, 100, 200, 500 μgm. $\times 10^{-4}$ respectively. The most sensitive range is 0·5–50 μgm. $\times 10^{-4}$ per 50-ml. culture solution. The test flasks or Petri dishes are sterilized and inoculated with four drops of a spore

Table 1. Relation between Molybdenum Status of Culture Solution and the Growth of *Aspergillus niger* after Six Days Incubation at 25° C.

μgm. Mo in 50 ml. culture solution	Description of mycelium and sporulation	Dry weights of fungus (mgm.). Mean of six determinations	*p*H of culture solution after incubation
0	Thin isolated strands of mycelium, entirely mucous	57	2·56
0·0001	Thin strands of mycelium, forming thin pellicle	114	2·92
0·0005	" " " "	174	3·49
0·001	Thicker pellicle, entirely mucous	275	3·58
0·002	" " " "	400	3·88
0·005	Occasional black spores on small islands of white hyphal growths alternating with mucous areas	537	1·67
0·01	Thicker mycelium, scant sporulation	638	2·18
0·02	Thick undulating mycelium, abundant sporulation	795	2·19
0·05	Very thick mycelium, complete black spore cover	950	2·10

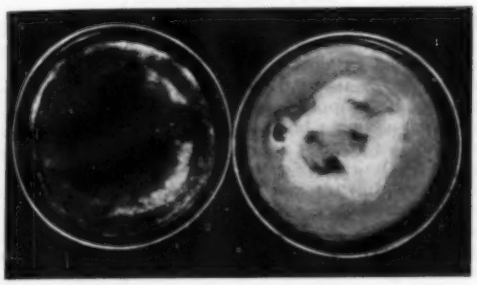
Table 2. Relation between Visual Symptoms, Molybdenum Status of Cauliflower (Leaves) and Soils

Location	Parent material of soil	Visual symptoms in cauliflower	Chemical analysis of cauliflower leaves. (Mo as μgm. per gm. dry weight)	Bio-assay of Mo in soils as μgm. per gm. air-dry soil
Long Ashton, Somerset	New Red Sandstone	No 'whiptail' 'Whiptail' symptoms, rudimentary aborted growing-points, absence of leaf lamina	1 to 5	> 0·5
Bromham, Wilts	Lower Greensand		0·02–0·10	0·01
St. Ives, Cornwall	Devonian	"	0·02–0·08	0·015–0·03

suspension of *Aspergillus niger* and incubated at 25° C. for six days. In Table 1 are given details of the growth series.

It is important to take soil samples for test from the rooting zone of the plants. Half-gram portions of air-dried soil are put in the sterilized culture solutions free from molybdenum, and then after inoculation the flasks are incubated as for the standard series. Three results of the bio-assay method are shown, together with results of other methods in Table 2. The two 'whiptail' soils were kindly supplied by Dr. William Plant from his experimental centres[16].

It is clear from Table 2 and the accompanying illustration that there are significant differences between molybdenum-level of 'whiptail-free' soils and those from areas where 'whiptail' symptoms in cauliflower are pronounced. The range of values so far obtained for soils deficient in molybdenum is 0·01–0·03 μgm. molybdenum, whereas normal soils usually have more than 0·5 μgm. molybdenum per gm. air-dry soil.



(*a*) Soil from Long Ashton showing an adequate molybdenum level (> 0·5 μgm. per gm. air-dry soil)

(*b*) Soil from 'whiptail' area showing a deficiency of molybdenum (0·03 μgm. per gm. air-dry soil)

The extreme sensitivity of the bio-assay method for the determination of levels of molybdenum, associated with sufficiency and deficiency of the micronutrient in soils, makes it preferable to chemical methods which are relatively ineffective for such a low range of values.

A full account of this and related work will appear elsewhere. [Feb. 22.

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EFFECT OF *p*H ON THE BIOLOGICAL ACTIVITY OF WEAK ACIDS AND BASES

By E. W. SIMON
Department of Agriculture, Oxford

A RECENT study[1] of the toxicity of some simple nitro derivatives of phenol to the fungus *Trichoderma viride* revealed a general relationship between *p*H and the toxicity of a weak acid or base. The upper curve in the accompanying graph shows the effect of *p*H on the concentration of a weak acid required to produce a standard response, such as bacteriostasis, from the test organism. Changes of *p*H have no influence on toxicity at *p*H-levels below *pK*; but at higher *p*H-levels the concentration required for the standard response increases rapidly, indicating a fall in toxicity. The concentrations of undissociated molecules corresponding to these total concentrations of weak acid are shown by the lower curve, and it will be seen that the concentration falls at *p*H-levels above *pK*. It has been pointed out[1,2] that since a constant concentration of undissociated molecules does not produce the same response at each *p*H-level, it cannot be held that the undissociated molecules alone are responsible for toxicity.

It has now been shown that *p*H influences many other biological activities of weak acids and bases and that the magnitude of the effect of *p*H is in each case of the same order as that shown in the illustration. In addition to the original observations on *Trichoderma*, the effect of *p*H on the following activities has been investigated; where no reference is given, the work is original.

(*a*) Inhibition of the respiration of bakers' yeast by the nitro derivatives of phenol.

(*b*) Inhibition of yeast respiration by iodoacetic and hydrazoic acids[3], hydrocyanic acid, hydrofluoric acid, *n*-butylamine and phenyl hydrazine.

(*c*) The toxicity of various weak acids and bases to bacteria, fungi, insect eggs, Protozoa, etc., for which data are available in the literature[1].

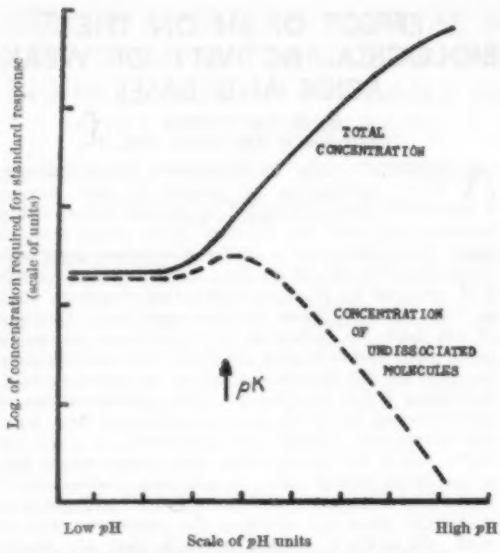
(*d*) Inhibition of yeast fermentation by 3 : 5-dinitro *o*-cresol.

(*e*) Stimulation of yeast respiration by low concentrations of 3 : 5-dinitro *o*-cresol.

(*f*) The activity of β-indoleacetic acid and similar acids in the pea test[3], and of β-indoleacetic acid in the oat cylinder test.

(*g*) The activity of *p*-amino benzoic acid in promoting the growth of a *Neurospora crassa* mutant[4], and of nicotinic acid in promoting the growth of *Staphylococcus aureus*[5].

It is clear from this list that the illustration represents the effect of *p*H on a very wide range of biological activities varying from toxicity to growth-promotion. The figure is based on an examination of more than eighty graphs, and the upper curve can be used to predict the effect of a given *p*H change on the activity of a particular weak acid or base. For example, it provides a basis for comparing the experimental results of authors who have used a respiratory inhibitor or a growth substance at different *p*H-levels. It may also be of value in measuring the activity of a range of weak acids. The activity of a weak acid, as determined by experiment, depends not only on the intrinsic activity of the compound but also on the *p*H at which activity is measured. It has been shown[1] that the measure of activity most appropriate for studies of the relation-



The effect of pH on the concentrations of a weak acid that are required to give a standard response from the test organism. The corresponding graph for a weak base is obtained by reversing the pH scale

ship between activity and chemical structure or physical properties is the activity measured at a pH at which there is little or no dissociation. A pH of 2 or more pH units below pK was recommended; but this may not always be practicable. Thus there are few organisms that could be used to measure the activity of a carboxylic acid of pK 4 at a pH of 2. In such a case, the measurements should be made at a convenient pH, say pH 7, and the graph can then be used to make a correction for the varying degrees of dissociation of the different compounds.

Several departures from the simple relationship shown in the graph have been found, and work on them is still in progress. One of the most interesting exceptions is observed when the test organism is large in comparison with the volume of the external solution, as, for example, when 3 : 5-dinitro *o*-cresol is sprayed on to seedlings[5] of mustard. The pH of the spray solution has only a very slight effect on toxicity (between pH 4 and pH 8 toxicity only changes by one-hundredth of that shown in the graph)[6]. There are two principal paths by which 3 : 5-dinitro *o*-cresol can enter the leaf tissue—diffusion in the vapour phase through the stomata, and penetration in the liquid phase through the cuticle followed by passage from cell to cell within the tissues. It is suggested that in either case the toxic material will always reach the cells at about the same pH-level—a pH related to that of the cells and scarcely affected by the pH of the spray solution. If steps are taken to ensure that the individual cells of the leaf are bathed in the buffered toxic solution, for example, by vacuum infiltration of leaf disks of mustard, it is found that pH changes influence toxicity to the extent shown in the graph.

In a similar way, the full influence of pH on toxicity is masked in other instances where a small quantity of a buffered solution of the active substance is applied to a relatively large bulk of tissue and is transported from cell to cell within the tissue, for example, the *Avena* curvature test[7], the tomato leaf epinasty test[8] and the rooting response of tomato cuttings[9].

This work will be presented for publication in detail elsewhere.

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INFILTRATION TO UNDERGROUND OF RAINWATER

By Dr. V. L. BOSAZZA
Barkly Road, Johannesburg

THE manner in which rainwater reaching the earth's surface is distributed has rarely been determined in detail, and then only in very local conditions. Its importance in modern agriculture[1] has not been appreciated fully, for extensive determinations have not been made. Lysimeter experiments are not, of course, recent innovations; but how far their results can be extrapolated to a catchment area is a very difficult matter to determine. Run-off and rainfall data have reached a high degree of accuracy[2], and in most cases the evaporation from free water surfaces is also available; but how to relate these and deduce the infiltration to underground is not a simple matter. Naturally a great deal will depend upon the type of vegetation, and for cultivated areas this is going to vary according to the crop[3].

South Africa is dependent upon underground water, and the infiltration to underground is of very great importance. For certain reasons, lysimeter experiments, which may be useful for agricultural experiments, may be dangerous to apply in wider hydrological problems. Theron's[4] experiments near Pretoria, for example, have limited application over South Africa. For example, our rainfall is highest in the mountainous areas and our mountain slopes are mainly noted for the waste rock that fill the foothills[5]. Run-off is nil in these structures, and water rapidly moves through the open texture of the boulder gravels and soon is safe from evaporation losses. It is probably in such areas that more than 50 per cent of the total precipitation goes to underground, whereas in other areas the order is that indicated by Theron, say 3 per cent.

The late Dr. A. L. du Toit[6] approached the problem in another manner. On the eastern portion of the Witwatersrand, the terrain is flat and consists of gently undulating dolomitic limestones with a variable covering of clays and sandstones of the Karroo System. The older rocks of the Witwatersrand System are also relatively flat-lying and have been extensively mined, so that the water pumped from these mined areas represents a very high proportion of the underground water of the area. Du Toit worked out that the water pumped out amounts to about 3 per cent of the total rainfall of the area. Here is a case of a gigantic lysimeter, and the method could be applied more extensively. For example,

Typical rock structure just below the soils of the Dolomitic limestones. The joints have been opened up by solution and water is now confined to a channel, thus builds up a greater head than if distributed evenly laterally and hence feeds to the underground reservoirs. To reconstruct this in a lysimeter or even simulate it in an approximate manner would be very difficult if not impossible. Vast areas of the dolomite present this structure under a thin soil cover

the western extension of the Witwatersrand lends itself to the same experiment. Now the dolomite covers a very great area in South Africa and, owing to the fact that the rock develops very large and extensive solution channels and underground caves[7], lysimeter experiments of the order of a third of an acre or less (unless they take into account such efficient media for rapidly leading water underground) would give figures that are far too low for the infiltration to the dolomitic limestones.

The South African landscape from the Western Province through the Northern Cape, Free State and the Transvaal into Southern Rhodesia is characterized by closed drainage areas or pans. These pans collect appreciable volumes of water and should act as efficient structures for forcing water underground. However, the fact that most of them contain greater quantities of salts in solution than rivers in the same areas suggests that underground drainage is not a rapid matter, and it is possible that from salinity studies the infiltration to underground could be evaluated. The pans occur over many geological formations and all over South Africa, and it means that results would be of wide application.

Studies of several dams show that the infiltration to underground varies a great deal. In some cases there is an undoubted flow to voids in rocks deeper down; but in others there is a gain from a source which can only be underground water issuing from springs. Boreholes drilled along the edges of dams, although well below the water-level and only a short distance (less than 1,000 ft.), gave such small yields (less than 20 gall. per hr.) that lateral flow from the dam could not be great. Many of our dams, for example, Haartebeestpoort Dam, are built in fault lines[8], so that ample and permanent supplies of underground water occur on the downstream side.

It appears that, if the elements of the hydrological balance are to be determined in South Africa, the mines of the eastern and western Witwatersrand, coal mines of the Witbank area and the dams and pans of South Africa can give a great quantity of data on underground infiltration, and that such data may be far more generally applicable than lysimeter experiments—of course, only so far as the infiltration to underground is concerned. It is an unfortunate circumstance that in the case of the Orange Free State gold mines the presence in certain areas of artesian water in the sediments of the Ventersdorp System (water derived probably from the Basutoland Highlands) will prevent the pumpage from those mines being useful in the evaluation of underground recharge in that area.

The Okavango Delta in the northern portion of Bechuanaland could be used to great advantage[9]. Presenting probably a very close approach to a free water surface, evaporimeters plus flow measurements of this river could give a valuable guide to the amounts of water that are fed to underground, and hence of the underground waters of the southern Kalahari and parts of South-West Africa. This would be invaluable in the development of Southern Bechuanaland.

With anxiety being felt of the lasting qualities of our underground waters, it is remarkable that, in the low rainfall areas of the Karroo, boreholes and springs of great yield are found, for example, the flowing springs of Cradock and Aliwal North. West of De Aar in areas of rainfall less than 12 inches, fresh and saline boreholes of 2,000–8,000 gall. per hr. occur within close proximity. In these areas surface limestone and extensive sand stretches facilitate infiltration to underground, and hence a high proportion of the rainfall is made available for subsurface flow. While in high-rainfall areas probably only 3 per cent of the total precipitation (say, more than 24 inches per annum) goes to underground, in these areas 60 per cent of the 12 inches precipitation may rapidly filter to the subterranean storage and flow.

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BONE AND TOOTH SOCIETY

A NEW society has recently been formed which has the object of providing a discussion ground for those interested mainly, but not exclusively, in fundamental laboratory investigations in bones and teeth. At its first meeting on March 24, it was decided to hold quarterly meetings at which there would be symposia on various aspects of bones and teeth, and there would also be meetings for casual communications where there would be opportunity for discussion by a more specialized audience than might be met with at other scientific society meetings having a more general interest.

An interim committee to look after the Society's interests in various branches, during its formative stage, was elected as follows: Mr. Ivor Kramer, representing dental interests, Dr. C. H. Lack, clinical, Dr. J. J. Pritchard, anatomical, Dr. H. J. Rogers, biochemical, and Dr. H. A. Sissons, histological. Dr. T. F. Dixon, Institute of Orthopædics, Royal National Orthopædic Hospital, 234 Great Portland Street, London, W.1, was elected secretary.

The Society had its first scientific meeting at the Institute of Orthopædics, 234 Great Portland Street, London, W.1, on June 6. This took the form of a symposium on bone structure at which Prof. W. D. Newcomb took the chair. Dr. H. B. Fell discussed the origin and developmental mechanics of the

embryonic skeleton in warm-blooded animals, and described experiments relating to the origin of chondrogenic and osteogenic tissue in the early embryo, the capacity of embryonic skeletal tissue for regeneration and regulation and the relative importance of intrinsic and extrinsic factors in the gross anatomical development of the skeleton. Dr. H. A. Sissons gave an account of the microscopic structure of various types of bone, as seen in the mature skeleton and in embryonic development. He outlined the cellular processes concerned in endochondral and membrane bone formation, and discussed lamellar bone, non-lamellar bone, and osteoid tissue from the histological point of view. Dr. J. J. Pritchard described the evolution of bone structure. He gave a brief assessment of comparative, embryological and palæontological evidence, and referred to the earliest appearance of bone in the geological record. He discussed the question whether bone or cartilage appeared first in evolution, and the possibility of their simultaneous origin in view of the close ties between the two tissues. He also described the possible derivation of endochondral bone from membrane bone and the evolution of different types of bony structure culminating in the plastic Haversian systems of large mammals (and large extinct reptiles) with special emphasis on vascular patterns. Dr. T. F. Dixon showed how wide fluctuations in inorganic composition of bone occur under the influence of a variety of conditions; for example, as might be expected from the histological structure, in the same animal there are variations from one bone to another and in different parts of one bone. Dietary variations produce changes in composition and so on. From chemical and such physical examinations as X-ray diffraction patterns and differential solubility measurements, the mode of combination of the inorganic elements can be elucidated. There is still, however, disagreement as to the precise molecular composition. Dr. H. J. Rogers described experiments on the protein and mucopolysaccharide components of the organic matrix of bone, and gave an indication of the identity of the sugars present in the latter.

The Society proposes to have a full programme this winter; the next meeting will probably be held at the Eastman Dental Clinic, Gray's Inn Road, London, W.C.1, on October 3, when a symposium on "Tooth Structure" will be held.

MANAGEMENT AND WORKERS

AT their annual conference at Buxton in April 1950, members of the National Institute of Industrial Psychology pooled their theories and experience to formulate an ideal personnel policy for an industrial organisation. To give the proceedings greater reality, the organisers presented the conference with a detailed description of a hypothetical company about to begin production of a nutritious food-stuff.

Before splitting into five committees, the conference was given some general suggestions by Sir Patrick Hamilton, chairman of Henry Simon, Ltd., and Mr. D. S. A. E. Jessop, personnel director of the Brush Electrical Engineering Co. Sir Patrick thought that the schemes adopted should be capable of modification as the organisation developed and issued a warning against allowing concentration on modern techniques to obscure such principles as honesty, sincerity, fairness and approachability. Mr. Jessop said success would depend largely upon the employees' understanding of the firm's overall working, of its objectives and of their enthusiasm for the venture. The spread of knowledge of what was going on, the possibility of everyone having his suggestions or criticisms heard or acted upon if valid, was what he understood by joint consultation and control, and not the mere division of managerial responsibility among a committee. Effective co-operation depended upon mutual confidence and on assured security in return for a job well done.

The first committee to report back to the plenary session suggested selection methods for appointments to supervisory and management jobs, which would generally place employees in jobs in which they would succeed and find satisfaction. The training committee decided to arrange not only for appropriate training for every grade in techniques, processes and methods of work which would be new to them, but also for a general course on the firm's organisation and production. This would show how each individual or group contributed to the whole.

Another committee dealing with methods of work and environment set before itself the question of maximum output with the minimum of strain. It considered diverse ways of ensuring the cleanliness desirable in a food factory, the best hours of work for a labour force to be composed mainly of women, the prevention of noise, pleasantness of surroundings and general welfare.

A further committee was concerned to see that management direction should be disseminated quickly and accurately through the works and that those in authority should know what was happening below and deal quickly with suggestions of dissatisfaction. They recommended verbal reports to employees on management problems, policy and financial matters, close co-operation and exchange of information between foremen, shop-stewards and between one individual and his immediate subordinate as well as the usual methods of spreading information.

The only committee to show a serious difference of opinion was that concerned with methods of payment. The majority of its members wanted generous weekly time-rates and the others some form of payment by results. All were agreed that wage-rates should be based on work measurement and some form of job evaluation and that a pension scheme and ultimately a profit-sharing scheme should be introduced. The majority believed that maximum output could be achieved by good supervision and encouraging a good team spirit; the minority that individual incentives are necessary in an imperfect world.

The final speaker was Mr. Giles Howard, of Hayward–Tyler and Co., Ltd., who said he would delegate responsibility within the firm and would see that there would be no over-ruling from above. But though responsibility was granted from above, they must remember that authority came from below. The firm's policy would be wise not clever and based on Christian ethics which were not incompatible with efficiency.

Summing up, General Sir Ronald Adam, chairman of the Institute, said that successful methods of selection using job analysis could be put into operation in industry now, as could efficient training for supervisory posts. Good methods of disseminating knowledge throughout a firm existed and, given the right attitude, could be successful. He was in favour of selection methods being applied to rank and file jobs.

LETTERS TO THE EDITORS

The Editors do not hold themselves responsible for opinions expressed by their correspondents. No notice is taken of anonymous communications

Thickness and Structure of the Membrane of the Human Red Cell Ghost

When mammalian blood is mixed with a large volume of glycerol, the red cells are hæmolysed and produce spherical ghosts of about the same diameter as red cells of spherical form. The membrane of the ghosts is birefringent; the optical axis lies radially, and the sign of birefringence is negative with respect to the tangent (Fig. 1). Since the ghost membrane shows little or no birefringence in saline, the negative intrinsic birefringence shown in glycerol must be compensated in saline by positive form birefringence. Schmitt, Bear and Ponder[1] concluded that the negative birefringence was due to radially oriented lipoid molecules, and that the strength of the birefringence was such that it must have been due to a layer of lipoid many molecules in thickness. It is now, however, known from physical and chemical measurements[2] that there is only enough lipoid present in a ghost to form a continuous layer over the surface about 50–100 A. in thickness (two to four molecules). The rest of the ghost is made up of the fibrous protein stromatin, in quantity sufficient to form a layer 50–150 A. thick when dry. No measurements of the thickness of the wet membrane have been made hitherto.

Fig. 1. Human red cell ghost in glycerol. Polarized light with compensation. × 2,300

I have developed a method of measuring the thickness of spherical or cylindrical membranes under certain conditions. It consists in measuring the retardation along a radial line which cuts the edge of the membrane. This gives a curve of retardation against radial distance. The shape of this curve is determined by the thickness of the membrane and the diffraction pattern in the microscope. The diffraction pattern can be calculated from theory and has been checked against models. When the diffraction pattern is known, the thickness of the membrane can be determined. This method has been applied to the human red cell ghost in glycerol, and the thickness of the wet membrane comes out at about 5000 A., or $0{\cdot}5\,\mu$, with an error of approximately $\pm\,0{\cdot}2\,\mu$.

A rough check on this figure has been obtained by centrifuging ghosts (produced by hæmolysis with distilled water) with forces up to 110,000 *g*. The ghosts pack down to a volume about equal to that occupied by the same number of red cells. This might be expected, since a ghost membrane $0{\cdot}5\,\mu$ thick would occupy about 55 per cent of the volume of an intact red cell.

This figure of $0{\cdot}5\,\mu$ is surprisingly large, and is about ten times greater than previous estimates. Ponder[2] estimates the wet thickness of the red cell membrane to be 300–400 A. Evidence from electrophoresis, wetting properties and permeability indicates that the lipoid is predominantly at the surface. The membrane must, therefore, be largely composed of hydrated protein (stromatin), and the protein must be responsible for most of the negative birefringence. Taking the dry thickness between 50 and 150 A., it seems that the stromatin is in a gelated state at a concentration of between 1 and 3 per cent.

The red cell is shaped like a biconcave disk, and it has been something of a mystery how this apparently unstable shape is maintained if the envelope is only a few molecules thick. If, however, the membrane is as thick as $0{\cdot}5\,\mu$, the dimensions of the intact cell show that the inner edges of the membrane will just touch in the middle of the disk. The shape would then be much more stable.

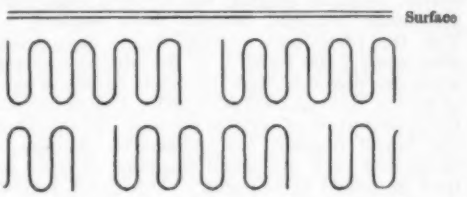

Fig. 2

Since a membrane of this thickness will occupy about 55 per cent of the volume of the intact red cell, it must contain large quantities of hæmoglobin within its structure. This may settle the controversy whether the red cell is a balloon filled with hæmoglobin in solution, or whether it is a solid jelly containing hæmoglobin. A red cell largely made up of a thick membrane containing hæmoglobin will fit the evidence for both these points of view.

This measurement of thickness indicates that the radial orientation in the membrane which causes the negative intrinsic birefringence is due to protein rather than lipoid. This implies that the membrane exhibits a new type of protein structure unlike the conventional picture of protein chains lying tangentially in the surface. A possible explanation is that the long stromatin molecules are arranged in looped bundles, like squibs or Chinese crackers. The bundles may be supposed to lie with their long axes running at random in the plane of the surface, but with the main parts of the protein chains within them lying radially (Fig. 2).

Such an arrangement would give the required negative intrinsic and positive form birefringence. A somewhat similar arrangement has been postulated by Rudall[3] to explain the cross-β X-ray pattern of epidermin, and Perutz[4] believes that there are looped protein-chains in hæmoglobin; but this is, I believe, the first evidence that such an arrangement may occur as part of the normal protein framework of living cells.

It is possible that other cell membranes may have a similar protein structure, since the membranes of amœbæ[5] and of sea urchin eggs[6] also show an increase in negative birefringence on immersion in liquids of high refractive index. It would, however, require more evidence than is yet available to prove this.

A full account of this work will be published elsewhere.

J. M. MITCHISON

Zoological Laboratory,
Cambridge.
April 26.

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Unusual Phosphatic Material in the Sutton Hoo Ship Burial

In the course of an investigation to determine whether there was a body in the Sutton Hoo ship burial[1], chemical analysis has revealed some unusual phosphatic material derived from calcined bone. That this phosphatic material should have persisted after some 1,300 years is of the utmost importance when one considers that the acidic nature of the soil at Sutton Hoo[2] (subsoil sand, *p*H 4·5) does not favour the preservation of skeletal remains. In the whole of the burial deposit, the excavators thought they recognized only one small fragment of bone which they described as unburnt[3]. This piece, cancellous and brown in colour, was found on top of the largest of the silver dishes in close association with many fragments of wood, bark and iron. From visual examination only, a distinguished anatomist agreed with the excavators; but the opinion of others, based on more detailed examination, was that the fragment was not bone.

With its true nature still in doubt, the material came back to the British Museum Laboratory for chemical analysis. This showed it to be essentially a hydrated ferric phosphate containing only traces of calcium. When treated with dilute hydrochloric or nitric acids, minute carbon particles remained, and there was no trace of the collagenous structure that forms the residue when unburnt bone is so treated. The mode of distribution of these carbon particles throughout the material was seen, under the microscope, to be closely similar to that of the carbon particles in calcined bone, and there seems little doubt, therefore, that this phosphatic material was derived from this source.

A probable mechanism for its formation is suggested by the conditions under which it was found; while the acidity of the soil would favour the dissolution of calcined bone, the diffusion of corrosion products from the adjacent iron fragments into the bone structure would, by the deposition of insoluble ferric phosphate *in situ*, tend to form a 'cast' of the shape of the original material. This process of cast formation would be most likely to occur in those fragments of calcined bone actually in contact with metallic iron. In fragments remote from iron, it is probable that dissolution of the inorganic portion would proceed to finality with consequent loss of structure, thus releasing phosphate ions into the surrounding area. Where these met with iron corrosion products, amorphous ferric phosphate would be formed. Examination of all the material collected from the top of the silver dish supports this view. Besides other fragmentary examples of casts derived from calcined bone, a high proportion of which are 'cemented' to iron or its corrosion products, many pieces of wood were recognized to be heavily impregnated with amorphous ferric phosphate.

The formation of an insoluble product from burnt bone by contact with corroding iron under soil conditions that are unfavourable to the survival of bone (burnt or otherwise) is of considerable importance to the archæologist. The fact that this secondary material may be mistaken for unburnt bone (as, indeed, it was) will serve to emphasize the necessity of a very careful chemical examination of all fragments even remotely resembling bone, found in similar circumstances, particularly when questions of cremation or inhumation are involved.

A full report of the investigation will appear elsewhere.

H. BARKER

Research Laboratory,
British Museum,
London, W.C.1.
May 20.

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Effect of Posture on Involuntary Eye Movements

Lord and Wright, and afterwards Lord[1], have published records of involuntary movements made by the eye during fixation, showing excursions as great as twenty minutes of arc, whereas Hartridge and Thomson[2] only found movements of about one-tenth of this amount. The former workers had their subject in the prone position and looking upwards, in the interests of head fixation, while the latter had their subject erect and used a technique designed to discount the effects of head movements.

It seemed likely to me that these very different results were probably due to the loss of the support that the eye gets from Lockwood's ligament[3] when the subject is prone, rather than to any differences in the recording technique of these two sets of workers. It also seemed probable that if the difference in the size of the involuntary movements in these two positions was real, there should be an accompanying change in visual acuity.

The test object used to verify this assumption was a set of Landolt's broken rings, black circles of stroke thickness t and overall diameter $5t$ with a gap of width t at some point in their circumference. These were drawn in a symmetrical pattern on a square card. When in the prone position, the subject saw the card lying beside him on the floor, through a mirror fastened to the ceiling at an optical distance of 5·5 metres. The same mirror and the same optical distance were used for the erect position. The actual illumination on the card could not be recorded; but it was of the order of thirty foot-candles. In each case the same bulb was used at the same distance, and the equality of illumination was checked with a photo-electric exposure meter. Three sizes of ring were used, in which the element t subtended approximately 65″, 50″ and 40″ at the subject's eye, so that the diameter of the largest subtended about 5·5′.

In the prone position, subject *A* resolved all ten 50″-rings without error with each eye separately. Subject *B* made one error with his right eye and two

with his left; neither subject could resolve any 40″-rings. In the erect position subject *A* made one error on the 40″-rings with each eye; subject *B* made one error with his right eye and none with his left. As a precaution against learning, advantage was taken of the symmetrical design of the test chart to turn it between observations and so produce a new arrangement.

CHARNWOOD

108 Eccleston Mews,
Belgrave Place,
London, S.W.1.

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Effect of a Posture Change on Head and Monocular Fixation Eye Movements

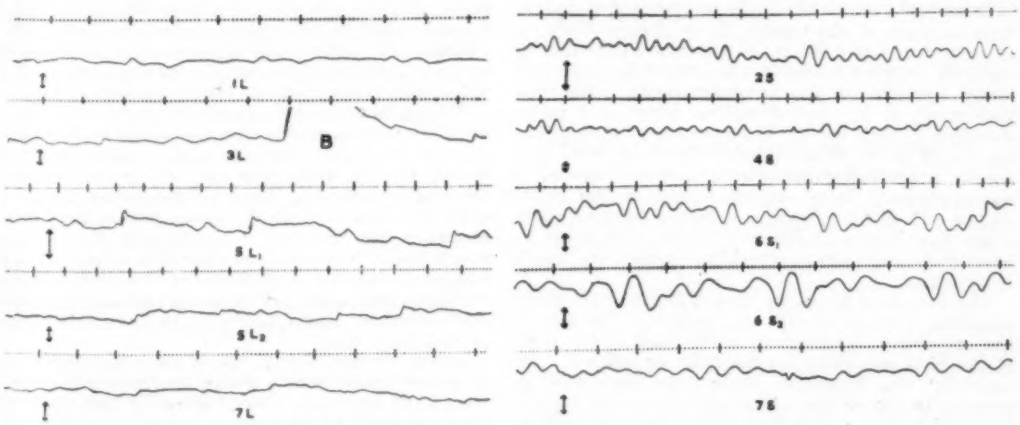
BINOCULAR fixation eye movement records[1] for subjects in the sitting position revealed a striking difference from monocular records[2] obtained with the subject supine. To decide whether the change of posture or the change to binocular vision was responsible for the difference, monocular fixation movements of the right eye have been investigated for seven subjects in the sitting position.

The method[1] of recording the eye movements is, in principle, identical with the photo-electric corneal reflex method used for supine observations[2]. At present, however, it is only possible to record the movements in one direction at a time. Head movements have also been recorded for those of the subjects whose teeth are sufficiently widely spaced to permit the rigid attachment of an artificial cornea to the skull by means of a dental regulation band; the artificial cornea was situated in front of the subject's right eye.

Head movement records for subjects W.D.W. and R.S.L. are shown in figures 1*L* and 2*S* respectively. As in the supine case, the movements are periodic, the period probably corresponding to that of the heart-beat. Day-to-day variations were found in the amplitude of the head-movement pattern. The average value of the maximum movement (about 0·025 mm. for both subjects) is some two and a half times larger than that found for W.D.W. in the supine position; moreover, the maximum displacement takes place sideways, whereas in the supine position it occurred longitudinally. The magnitude of the longitudinal movement is approximately the same for both positions.

Figs. 3–7 show eye records for some of the subjects for fixation, with the right eye, of a bright disk of angular diameter 1′. In almost all records the head-movement pattern can be picked out; its magnitude was found to show day-to-day variations: Figs. 6 S_1 and S_2 are side-to-side records for L.C.T. taken on May 10 and 31 respectively. Eye movement records for subjects W.D.W. and R.S.L. are shown in Figs. 3*L* and 4*S* respectively; the average maximum value of the head movements, as deduced from the side-to-side eye records, is 0·033 mm. for both these subjects. Whether the difference between this value and that obtained from the head records is due to day-to-day variations or to the fact that the subjects were not fixating when the head records were obtained will receive further investigation. The average maximum value of the head movements of all subjects was 0·038 mm.; the lowest average maximum value, of 0·021 mm., was found for subject M.P.L. (Fig. 7) and the highest, of 0·047 mm., for subject L.C.T. (Fig. 6).

The effect of the change of posture on the parts of the eye records presumably produced by rotations of the eye is also striking. For subjects W.D.W. and M.P.L. (Figs. 3*L* and 7 respectively), the average interval between the rapid flicks[2] is increased about threefold, that is, to 1·3 sec. for W.D.W. and to 2·3 sec. for M.P.L.; for subject R.W.G.H., however, for both positions, the average interval is 0·86 sec.: Figs. 5 L_1 and L_2 are up-and-down records for R.W.G.H. for the supine and upright positions respectively. Records in the supine position for the other subjects are not available; for the upright



Up-and-down movement denoted by *L*; towards the time line corresponds to an upward movement.
Side-to-side movement denoted by *S*; towards the time line corresponds to a leftward movement.
1 and 2, head movements for W.D.W. and R.S.L. respectively.

3–7, eye records for W.D.W., R.S.L., R.W.G.H., L.C.T. and M.P.L. respectively.
Time (increasing to right) marked by dots, 50 per sec., and by lines at 1/5 sec. intervals.
Amplitude shown at side: height of arrowed line represents a rotation of 20′, assuming the separation of the centre of curvature of the cornea and the centre of rotation of the eye is 5·3 mm.

position, their average intervals between flicks are 0·94, 5·2, 5·3 and 12 sec. for R.N.W., L.C.T., P.B.W. and R.S.L. respectively. The posture change has little effect on the duration (0·02–0·03 sec.) and magnitude (2–25′) of the flicks. The frequency and character of the blinks (for example, *B*, Fig. 3*L*) are apparently unaffected by the alteration of the subject's position.

The increase in the magnitude of the head movements on sitting up is in accordance with earlier observations[3], and is not surprising in view of the fact that greater muscle tone is associated with the upright than with the supine position. Moreover, for the sitting-up position, the head was not supported at the back as it was in the supine case; it is therefore the more difficult to understand why, in the upright position, the greatest displacement occurs sideways. That a change of posture should have an effect on the eye movements is to be expected; for the extra-ocular muscle tensions are influenced by labyrinth impulses and the stimulation of the otoliths is different for the supine and upright positions. It is not immediately obvious why, in the case of R.W.G.H., change in posture has no marked effect.

I am very grateful to Dr. W. D. Wright and Mr. R. S. Longhurst for recording my observations and for acting as subjects; I wish to express my thanks also to the other subjects: Dr. L. C. Thomson and Messrs. R. W. G. Hunt, P. B. Watt and R. N. Wilson. I gratefully acknowledge the continued financial support of the Medical Research Council.

MARY P. LORD

Technical Optics Section,
Imperial College of Science and Technology,
London, S.W.7.

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Phoretic Association between *Afronurus* and *Simulium* Species, and the Discovery of the Early Stages of *Simulium neavei* on Freshwater Crabs

DURING the course of routine sampling of the gravel bottom fauna of the Sagana River (Kenya Colony), at an altitude of 5,865 ft. in connexion with fishery research on trout foods, it was noticed in 1948 that many nymphs of the ephemeropteran *Afronurus peringueyi* (E.-P.) had *Simulium* larvæ and pupæ attached to their backs. Examination of these pupæ by one of us (J. McM.) showed that they were of a species not hitherto described; and this species is not apparently found anywhere else in the river. 49 per cent of all *Afronurus* collected from all parts of the river between 5,900 and 5,600 ft. were found to have *Simulium* larvæ attached; pupæ are much more scarce.

The *Simulium* larvæ are always found in the same position, attached by the anal sucker to the side of the ephemerid nymph just at the base of the coxa of the hind leg, either on the right or left side. In captivity, the *Simulium* larvæ have been seen to move over the surface of the nymph in the typical 'looping' fashion; but they always come to rest in the position described with the head and body pointing backwards over the gills of the nymph (see photograph). Pupation occurs on the dorsum of the nymphal thorax, with the pupal filaments pointing backwards over the body of the host.

Living *Afronurus peringueyi* nymph, with *Simulium* sp. larva attached. × 9

It proved difficult in the laboratory to rear this interesting association; but adults of the *Simulium* species have now been bred out and will be described elsewhere. A most interesting feature of this association, which appears to be a phoresis, is the mutual timing of the various nymphal and larval stages. During the moults of the *Afronurus* nymph, accomplished in the usual manner by splitting along the dorsum, the *Simulium* larva may become detached for a short while until the moult is complete, and then re-attaches itself to the newly moulted nymph in the same position; or alternatively, the *Simulium* larva remains attached to the old nymphal skin, and then transfers itself to the newly moulted nymph when the moult is almost complete.

The *Simulium* larva always pupates after the *Afronurus* has completed its last nymphal moult; when the eclosion of the *Afronurus* sub-imago takes place, and the nymphal skin is finally cast off, the *Simulium* adult also emerges from the pupa. The emergence of both adults takes place in the hours of darkness within an interval of one or two hours. The ovipositing habit of the adult *Simulium* is not known.

The adults of this *Simulium* species which have been bred are so remarkably like the adults of *S. neavei*, the vector of onchocerciasis in the western parts of Kenya Colony, that they may easily be mistaken for it at first glance. Minor differences are, however, apparent, and no true *S. neavei* adults have been caught in the vicinity of the Sagana River. The resemblance, however, is so close that it immediately suggested that the early stages of *S. neavei*, hitherto undiscovered in spite of intensive searches in Kenya and elsewhere, might be found to have this unsuspected habit also.

It was known that *S. neavei* could be eliminated from an infested area by dosing the rivers and streams with DDT emulsion, a fact indicating that the early stages were to be found in such rivers and streams. One of us (J. McM.) therefore proceeded to Ngoina, near Kericho (Kenya Colony), in February 1950 in order to carry out further investigations. This area is a focus of onchocerciasis, and *S. neavei* adults are very numerous.

Catches made over a period of years indicated that *S. neavei* adults seem to prefer to live near the smaller rivers and streams, and accordingly work was begun on a small river passing through heavily wooded country, and having many small cascades and waterfalls in its course. Large numbers of the younger stages of various insects, as well as crabs and fish, were examined during a period of two weeks for evidence of such an association, with negative results. However, searches in two of the larger rivers, the Kipsonoi and the Sondu, soon produced evidence that there is a definite association between fresh-water crabs (*Potamonautes* (*Potamon*) sp.) and a *Simulium* sp. As many as ten larvæ have been found attached to the carapace of one crab, and the maximum number of pupæ observed was three. Adults bred from these pupæ appear to be *S. neavei*, and the male and pupa will be described in detail at a later date; the pupal respiratory organ has eight long slender breathing filaments, equal in length to the cocoon. The female has already been described by Roubaud.

The association between crabs and this *Simulium* species coincides with the distribution of *S. neavei* adults, whereas that between *Afronurus* and *Simulium* species seems to occur at a higher altitude well outside the *S. neavei* belts. Only one specimen of *Afronurus* collected in the Kipsonoi was found to have a pupa attached, and not more than twelve were collected in the Sondu during a period of six days; but in the higher Kiptiket River, 20 miles away and some 300 ft. higher, twenty nymphs with pupæ attached were collected during a period of two hours.

The crabs concerned seem to prefer to live in the rockier parts of the rivers, such as cascades, and no specimens have yet been caught on mud or other soft river-bed material.

Simulium–Afronurus associations have now been found in several Kenya rivers, and the whole problem is still the subject of study in all its aspects. Dr. G. Marlier, of I.R.S.A.C., Belgian Congo, has informed one of us (V. D. v. S.) *in litt.* that he has found similar *Simulium–Afronurus* associations in rivers in the Kivu Province of the Congo, apparently two species of *Simulium* being involved; Dr. Marlier is publishing a note on this subject elsewhere.

In conclusion, we wish to thank Mr. Hugh Copley, fishwarden, Kenya Colony, and Dr. T. Farnworth Anderson, director of Medical Services, Kenya Colony, respectively, for permission to publish this joint note.

VERNON D. VAN SOMEREN
River Research and Development Centre,
Nyeri Station, Kenya Colony.
J. MCMAHON
Division of Insect-borne Diseases,
Kisumu, Kenya Colony.
March 27.

Sulphamic Acid as a Test for Nitrate-reducing Bacteria

SULPHAMIC acid (aminosulphonic acid) decomposes nitrites quantitatively[1] with evolution of nitrogen gas according to the equation

$$NH_2.SO_3H + MeNO_2 \rightarrow MeHSO_4 + H_2O + N_2.$$

The reaction, which is very specific and strongly catalysed by hydrogen ions, may be used for the removal of interfering nitrites, for example, when testing for nitrates[2], or in water analysis as part of the Winkler method for dissolved oxygen determinations, where nitrites will cause serious error unless removed. For this latter purpose, according to Cohen and Ruchhoft[3], sulphamic acid possesses distinct advantages over sodium azide.

It seemed worth while investigating whether sulphamic acid had any value in bacteriology as a reagent for detecting nitrites in the nitrate-reduction test, for which it would appear it has not hitherto been used. Preliminary experiments to ascertain the limits of sensitivity of the reagent were carried out using a solution of sulphamic acid prepared according to the directions of Cohen and Ruchhoft (*loc. cit.*). This is a 4 per cent solution in 20 per cent v/v sulphuric acid. Standard solutions of nitrite were prepared from silver nitrite. The following technique was used. 1 ml. of standard nitrite was pipetted into a small test tube (7·5 cm. long by 8 mm. internal diameter). The tube was slightly inclined and 1 ml. of the sulphamic acid solution was pipetted down the side. By this method water blanks showed no bubble formation. In the test solutions gas bubbles were readily seen in concentrations of nitrite down to 5 p.p.m. (expressed as nitrogen).

One hundred cultures of catalase-positive cocci were tested for nitrate reduction both by the sulphamic acid technique outlined above and also by the usual modification employing the Griess–Ilosva reagents (sulphanilic acid and α-naphthylamine in acetic acid solution). All the cultures were examined by one test before the second test was applied. In this way, the result of one test on an individual culture was not known before applying the second test, thus avoiding any prejudgment of the result. The records showed that in each of the sixty-two cultures in which a positive result was noted with the Griess–Ilosva reagents, evolution of gas was observed with the sulphamic acid solution. No gas bubbles were seen in the remaining cultures.

A full account of the work and a critical survey of the two methods will be published elsewhere.

F. BAYARD HORA
AUDREY JONES
University, Reading.
April 20.

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Effect of Aspartic Acid on Growth of Plant-Virus Tumour Tissue

RECENTLY several workers have concluded that, under certain conditions, amino-acids can be assimilated intact by yeasts[1,2]. White and Munns[1] conclude that aspartic acid can be used as a source of nitrogen by yeast, and also that the carbon skeleton can be used if fermentable sugars are present (probably as energy sources). They found that when aspartic acid is added to the test medium in sufficient amount, the growth of yeast greatly exceeds that when only hexose sugars are present.

Results of this nature have been found by Nickell and Burkholder[3] working with virus tumour tissue from the sorrel plant (*Rumex acetosa* L.)[4,5] grown *in vitro*. It was found that aspartic acid could serve, to a certain extent, as a carbon source for the growth of this tissue. Nitrate was found to be the best source of nitrogen; but aspartic acid,

of all the other organic and inorganic nitrogenous compounds tested, alone approached nitrate in its effectiveness as the sole source of nitrogen. Moreover, when nitrate and sucrose were present in optimal concentrations, and when other environmental and nutritional conditions were optimal[6], the addition of aspartic acid caused a stimulation of growth proportional to the amount added, up to 0·032 *M*. Concentrations higher than this have not been tested. It is apparent that the stimulation of growth caused by aspartic acid in the presence of optimal amounts of carbon (sucrose) and nitrogen (nitrate) is due to some other reason than simply its utilization as a source of carbon or nitrogen or both. It is possible that aspartic acid, so important in the metabolism of many plant tissues, is in the present instance the limiting factor when the other optimal conditions are met. It might be mentioned, also, that when aspartic acid is present in the medium, the colour of the tumour tissue is much greener than when grown under any other conditions, except when starch is utilized as the carbon source. This suggests that aspartic acid may have some effect on the synthesis of chlorophyll in this tissue.

From the results presented above, it is suggested that in this case, too, aspartic acid can be assimilated intact by the tumour tissue.

L. G. Nickell

Brooklyn Botanic Garden,
Brooklyn 25, New York.
April 21.

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In vitro Inhibition of Growth of a Pathogenic Protozoan by a Derivative of Glutamic Acid

DL-N-(gamma-glutamyl)-ethylamine has been found to act as an antimetabolite of glutamic acid in the growth of *Staphylococcus aureus*[1]. The object of the present investigation was to study the influence of this substance on the multiplication of the parasitic flagellate *Trichomonas vaginalis*.

DL-N-(gamma-glutamyl)-ethylamine was prepared, as previously described, from DL-pyrrolidonecarboxylic acid and aqueous ethylamine[2]. *T. vaginalis* was grown in the absence of bacteria according to the method of Adler and Pulvertaft[3]. The medium described by Johnson[4] consists of a solid phase (liver infusion agar slant) and a liquid phase containing sodium chloride, phosphates, proteose peptone, blood serum and penicillin. The cultures were kept at 37° and passages were made every three to four days.

Various proportions of DL-N-(gamma-glutamyl)-ethylamine and L-glutamine were added to tubes containing 6 c.c. of the liquid medium over a liver infusion slant and nine-ten drops of the culture. Parallel experiments were carried out with the same amounts of DL-N-(gamma-glutamyl)-ethylamine and sodium L-glutamate.

Table 1. Effect of DL-N-(Gamma-Glutamyl)-Ethylamine on the Development of *T. vaginalis*

DL-N-(γ-glutamyl)-ethylamine	Development of *T. vaginalis* after 96 hr.
50 mgm.	+ + +
100	− − −
100	+ + +
135	− − −
150	− − −

Table 2. Effect of L-Glutamine and of Sodium-L-Glutamate on Inhibition of Development of *T. vaginalis* by DL-N-(Gamma-Glutamyl)-Ethylamine

DL-N-(γ-glutamyl)-ethylamine	L-glutamine	Development of *T. vaginalis* after 96 hr.
150 mgm.	10 mgm.	− − −
"	20	− − −
"	30	+ + +
	Sodium-L-glutamate	
150 mgm.	30 mgm.	− − −
0 "	60	− − −
	"	+ + +

As shown in Table 1, 135 mgm. of DL-N-(gamma-glutamyl)-ethylamine completely inhibited the multiplication of *T. vaginalis*, whereas 100 mgm. inhibited the growth occasionally. Table 2 shows that this inhibition is reversed by the addition of 30 mgm. of L-glutamine; while twice this amount of sodium-L-glutamate was without effect.

These results seem to indicate that in *T. vaginalis* DL-N-(gamma-glutamyl)-ethylamine acts as a competitive antagonist of glutamine rather than of glutamic acid, and that glutamine is obligatory for the development of a culture of *T. vaginalis*.

It was found necessary to use relatively high concentrations of the antagonist, probably because blood serum and liver infusion contain relatively high concentrations of glutamine[5]. Moreover, the varying results obtained with smaller amounts of the antagonist could be explained as due to variations in the concentration of glutamine in the media employed.

We are indebted to Prof. S. Adler, of the Department of Parasitology, Hebrew University, for providing the strain of *Trichomonas vaginalis* employed in this work.

A. Back
A. Sadovsky
N. Lichtenstein

Cancer Laboratories and Department of
Biological and Colloidal Chemistry,
The Hebrew University,
Jerusalem.
April 21.

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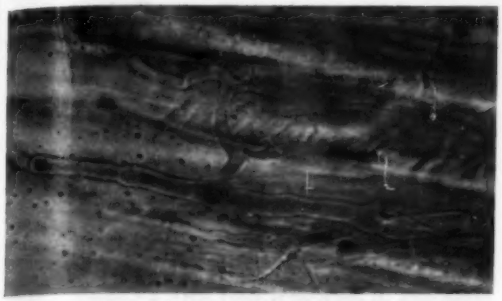
Problem of Wheat-Rust

Prof. Stakman in the United States, by continual breeding of resistant strains of wheat and by application of effective spraying at the appropriate time, has been able to minimize loss by rust; but in spite of his devoted labours for more than three decades and the ample facilities given by the U.S. Government, he has not been able to eradicate the wheat-rust from the country.

Examination of some samples of fresh and healthy Indian wheat seeds of this year showed the invariable presence of distinctly septate and branched fungal hyphæ in the subepidermal region of the seeds, just



Hyphæ of *Alternaria* sp. within the seed-coat of Indian wheat. (× 700)

beneath the testa within the tegmen of the grains (see Fig.), when the epidermis was stripped whole from such grains and stained with aniline blue. Aseptic culture from some such seed grains gave rise to *Alternaria* sp. in potato dextrose agar and malt agar tubes. When these grains germinated within the culture tubes, sections of the plumules and radicles showed the same septate and branched hyphæ within their tissues, which in pure culture produced *Alternaria* spores. Canadian wheats, recently received through the courtesy of Dr. W. F. Hanna of the Rust Research Laboratory of Winnipeg, when sectioned, showed the same septate hyphæ in the subepidermal region of wheats. Repeated isolation of mycelium of *Alternaria* sp. from surface-sterilized seeds indicated that the fungus remained within the seed tissues. Hanna Schwarz-Kraepalin[1], on examination of three hundred grains of wheat from different sources, always found fungal hyphæ on the inner side of the skin; she also found such internal fungus in rye, spelt, barley and oats. T. A. Oxley[2], in his attempt to obtain fungus-free wheat grains, found subepidermal fungus in several samples of 'Bersee' wheat. Whitehead *et al.*[3] isolated *Microascus trigonosporus* from surface-sterilized seeds of wheat; they hold that the "fungus persists within the enveloping tissues in dormant seeds of several crop plants with no apparent damage to host development", and their inoculation experiments gave no evidence of definite necrosis or reduced vigour of the treated plants.

It would be worth while to follow the growth of these internal fungi within wheat plants in an aseptic glass-house under controlled conditions, and to bring out the relationship, if any, between them and the external rust-producing fungus, *Puccinia graminis*, and finally to find out if the production of resistant or susceptible strains of wheat depends on the behaviour of these internal fungi. It is my experience in the course of my study of hereditary symbiosis in *Casuarina equisetifolia*[4] that some fungi act under certain environmental conditions as beneficial agents to hosts; under other conditions they may prove serious enemies.

Because of the great economic importance of wheat-rust, there should be abundant support for research from various angles. I suggest that intensive work should be carried out in all wheat-producing countries of the world to find out if such internal fungi are almost invariable associates of wheat plants. Mehta in 1935 estimated the loss in India due to wheat-rust at about 600 million rupees annually. Control of wheat-rust by the development of resistant wheat varieties has not been successful to date because new hybrids of rust fungi have always been effective against any previously resistant wheat. At present, about two hundred distinct strains of black rust are known, of which nine have been so far reported from India by Mehta; but there is every possibility that there may be other strains in this country which have not been identified as yet.

Further details of the work will be published elsewhere.

S. R. Bose

Botanical Laboratory,
Carmichael Medical College,
Calcutta.
July 12.

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Inhibition of the Growth of *Leuconostoc mesenteroides* by the Toxic Factor from 'Agenized' Zein: Reversal by L-Glutamine

The crystalline toxic factor originally isolated[1] from zein treated with nitrogen trichloride causes epileptiform fits in certain animals and inhibits the growth of *Leuconostoc mesenteroides P-60*[2]. The subsequent synthesis of the factor from methionine, reported[3] from this laboratory, indicates that it probably has the structure $CH_3.SO(NH).CH_2.CH_2.CH(NH_2)COOH$ which, formally, has some resemblance to that of glutamine.

Glutamine reverses the inhibitory effect of methionine sulphoxide, a close analogue of the toxic factor, on the growth of *Lactobacillus arabinosus*[4] and streptococci[5,6], and we have found that it also nullifies the toxic effect of the factor on *Leuconostoc mesenteroides*. Some typical data are given in the accompanying table. The toxic effect of the factor is apparently not specifically dependent on the groupings around the sulphur atom, as the lower homologue, $CH_3.SO(NH).CH_2.CH(NH_2)COOH$, synthesized from L-cysteine by our colleagues Dr. H. R. Bentley and and Mr. J. K. Whitehead, is ineffective at comparable concentrations.

These results may be of interest in relation to the neurotoxic properties of the crystalline toxic factor from 'agenized' zein. The significance of glutamine

Acid Production (17 hr. at 37° C.) by *Leuconostoc mesenteroides*, on a Full-growth Medium: Effect of Addition of Toxic Factor and L-Glutamine

Crystalline factor ($C_6H_{12}N_2O_2S$) from 'agenized' zein. Concentration $M \times 10^{-4}$	Crystalline factor ($C_6H_{12}N_2O_2S$) synthesized from L-methionine. Concentration $M \times 10^{-4}$	Lower homologue ($C_4H_{10}N_2O_2S$) synthesized from L-cysteine. Concentration $M \times 10^{-4}$	L-Glutamine. Concentration $M \times 10^{-4}$	Acid production. Mean titre (ml. of 0·01 N NaOH)
0	0	0	0	2·2
3·7	0	0	0	0·55
3·7	0	0	8·5	2·0
3·7	0	0	17	2·2
3·7	0	0	34	2·2
0	0	0	0	2·5
0	3·0	0	0	0·45
0	3·0	0	17	1·95
0	3·0	0	34	2·4
0	0	18	0	2·25

as a metabolite in nerve tissue has been reviewed by Archibald[7], and Waelsch and co-workers have demonstrated[8,9] the alleviating effect of L-glutamic acid in cases of *petit mal* epilepsy.

We are greatly indebted to Prof. F. E. King for a gift of L-glutamine.

J. G. Heathcote
J. Pace

Research Association of British Flour Millers,
Cereals Research Station,
Old London Road,
St. Albans.
June 21.

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Use of Spores Labelled with Radiophosphorus in the Study of the Respiratory Retention of Aerosols

In the study of respiratory infection it is important to determine the extent to which an aerosol is retained and the distribution of the retained particles. Retention has been studied, usually with inhomogeneous aerosols of particle-density well in excess of unity, particularly in relation to pneumoconiosis[1]; and viable counts of retained organisms have been made[2]. Difficulties arise in viable counts: disintegration of the head of, for example, a guinea pig and plating out of the resultant slurry is an unsatisfactory procedure, and naturally occurring organisms interfere. (We have found about 10,000 heat-resistant spores in normal guinea pig lungs.)

Distribution of retained aerosols of radioactive materials has been studied by Scott *et al.*[3]. The particle-sizes in this work were too inhomogeneous and the densities far too high to be relevant to bacterial aerosols; but the techniques suggested a most fruitful approach. Various workers have grown bacteria on media containing phosphorus-32 as phosphate: the radiophosphorus is taken into combination as nucleic acids, etc., and the labelled bacteria have been traced after injection[4–9]. For the study of respiratory retention we required a much higher level of induced radioactivity than had previously been used, since various considerations limit the total number of organisms to a comparatively low level.

Extensive studies of resting organisms in high radiation fluxes have been made; but nothing appears to have been published on organisms growing in such conditions. We had, therefore, to determine the highest tolerable activity of medium before studying the use of the active suspensions.

Experimental details. *B. subtilis* was grown on *CCY* agar[9] (less glycerophosphate) containing phosphorus-32 as disodium hydrogen phosphate up to 650 mC./litre. Spores were reaped after 45 hr., heated at 60° C. for 1½ hr., and washed at least six times to remove soluble phosphorus-32 salt. Typical harvests from 30 ml. of agar in an 8 oz. medical flat were:

	a	*b*	*c*	*d*
Radioactivity of medium (mC./litre.)	0	42·5	325	650
Viable spores per flat, × 10^{10}	11·0	6·7	1·6	1·0
Geiger-Müller counts per min., per flat of washed suspension, × 10^7	—	5·2	14·0	21·8
% of added phosphorus-32 utilized by spores	—	15·5	5·5	4·3

Guinea pigs have been exposed to aerosols of single organisms in apparatus used with a Collison spray[10] and to aerosols of larger particle-size generated from a spinning disk[11]. They are killed and the various tissues are digested in nitric acid for assessment.

Counts on suspensions have been carried out with *GM*.2 or *GM*.4 and window counters: *M*.6 liquid counters[12] have been used for aerosol samples collected by impingement in water and tissue digests, and have proved essential to the remarkable speed and simplicity of the experimental technique.

Results. (*a*) *Growth of organisms.* The viable yield on 650 mC./litre. medium is one-tenth that on inactive medium, but the opacity indicates about a quarter of the normal yield; the non-viable spores include a proportion that are seen, using a technique developed by Powell and Pearce[13], to attempt germination but fail to establish colonies (perhaps lethal mutants as discussed by Lea *et al.*[14]). The radiation dosage during growth is about $1{\cdot}8 \times 10^4$ rep.; MLD of about 4×10^3 rep. for vegetative organisms and 8×10^4 rep. for spores are reported[14]. Self-induced dosage in the reaped suspension is roughly estimated at 2×10^4 rep. in ten days; the viable count has then fallen to about one-half and continues to decay roughly exponentially.

(*b*) *Exploratory experiments.* Guinea pigs were exposed to aerosols of normal spores, and viable counts were made on disintegrated head, trachea and lungs. Further guinea pigs were exposed to aerosols of radioactive spores, and both viable and radioactive counts were made. These experiments showed that the radioactive measurements were far more convenient and probably gave sufficiently accurate results. Exposure was also made to aerosols of the supernatant fluid from centrifuged radioactive suspensions: this showed that the water-soluble activity (usually less than 5 per cent of the total) did not significantly affect results.

(*c*) *Retention of particles of known size.* Exposures under (*b*) gave information about single organisms (nominally 1 μ particles). An apparatus[11] developed in this Department has now been used for exposure to homogeneous aerosols of 'dry' particle diameter 4–10 μ. Typical results are:

Particle size	No. of guinea pigs	% of total retention in Head	Trachea	Lungs	Trachea and lungs combined
1 μ	6	29	19	52	71
	6	29	13	58	71
	6	29	13	58	71
4 μ	8	65	—	—	35
10 μ	8	98	1	1	2

The total intake of individual guinea pigs in each experiment varies over a range of about 1–3; but the distribution remains remarkably constant.

(*d*) *Miscellaneous observations.* Only the noses of the animals are exposed to the aerosol, but a substantial deposit on the skin is found; it must therefore be carefully removed before digesting the head. Substantial counts are obtained from the stomach in some cases: time-lapse before dissection is obviously important in relation to ciliary removal (*c.* 2 cm./min.).

It is found that spores are strongly adsorbed on glass, which accounts for the loss of viable count from a dilute suspension both when it is stored and when it is agitated by shaking or airstream. In an experiment with a radioactive suspension the following was found:

Days storage		% of original counts Viable	Radioactive
0		(100)	(100)
1		88	98
2		62	91
3		79	86
4	Tube shaken 10 min.	16	24
	Shaken further 25 min.	13	18

'Manucol' (sodium alginate) suppresses the effect of agitation on viable counts: it also suppresses the drop in radioactive count:

		Geiger-Müller counts Zero	4 hr.	24 hr.	After agitation
'Manucol'	Nil	1,821	1,405	1,248	721
	0·9%	2,044	1,978	1,923	1,935

Since the radioactive count would be unaffected by clumping, the loss must be due to removal of spores from suspension. If the vessel is rinsed with water and then extracted with hot nitric acid, the extract yields most of the missing radioactivity.

We had hoped to trace the exact distribution of retained spores by autoradiographs; but it has proved impossible to achieve anything near the level of activity per spore that is necessary.

The Atomic Energy Research Establishment, Harwell, has supplied the phosphorus-32 and has given valued assistance. The Chief Scientist, Ministry of Supply, agrees to publication of this communication.

F. E. Buckland
G. J. Harper
J. D. Morton

Microbiological Research Department,
Porton, Wilts.
May 15.

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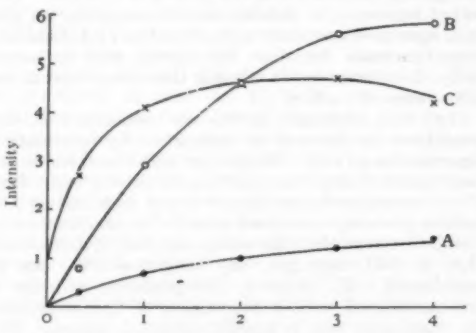
Effects of Histone and other Proteins on the Feulgen Reaction

When deoxyribonucleic acid is subjected to the Feulgen reaction, the pigment which develops may be soluble in water or dilute acid, as the Stedmans[1] have suggested. If deoxyribonucleohistone extracted from nuclei of beef spleen by the method of Mirsky and Pollister[2] is treated in the same manner, the colour develops almost exclusively on the precipitate.

The concentration of hydrochloric acid used was 0·05 *N* throughout the work described here, and the introduction of buffer solutions was purposely avoided. The effects of histone upon the Feulgen reaction not only make the pigment insoluble, but also increase the colour intensity. Highly polymerized deoxyribonucleic acid extracted from beef spleen by the method of Petermann and Lamb[3] was precipitated with an appropriate amount of histone dissolved in dilute hydrochloric acid, the precipitate formed being retained after hydrolysis for three minutes at 100° C. Thymic acid was precipitated with histone from a completely clear solution obtained by the hydrolysis of deoxyrobonucleic acid. It was found that an addition of histone at any time in the course of the Feulgen reaction increased the intensity of the reaction very remarkably. When equal amounts of histone and deoxyribonucleic acid were mixed before hydrolysis, the colour developed almost exclusively in the precipitate. With smaller amount of histone, the precipitation of the dye was incomplete and the enhancement of the colour intensity was less prominent, while addition of an excess of histone made the precipitate soluble again, so that the intensity of the reaction could easily be determined as follows. To each of 0·5 ml. of a 0·1 per cent solution of deoxyribonucleic acid were added (*a*) 4 ml. of hydrochloric acid and (*b*) 4 ml. of a 0·1 per cent solution of histone in hydrochloric acid, and hydrolysis was carried out by heating for three minutes at 100° C. 5 ml. of hydrochloric acid and 0·5 ml. of Feulgen reagent were added to each of these solutions after rapid cooling. The colour developed was compared at intervals with an arbitrary standard, of which the colour had been stabilized by standing more than forty-eight hours. The results are shown in the accompanying graph.

This remarkable colour-enhancing effect is, however, by no means confined to histone, for proteins such as egg albumin, casein, ribonuclease and also lanthanum chloride exhibit similar properties to some extent. Therefore, it seems very probable that the 'adsorption' of the dye is confined not only to chromosomin, as postulated by the Stedmans[1], but is also



A, Without histone; *B*, with histone; *C*, ratio of *B* to *A*

shown by proteins in general. Although the nature of the effect described here is not understood at present, it is evident that for the enhancement of the reaction the pigment formed need not be precipitated.

In this connexion it is noteworthy that microscopic sections exert similar effects on the Feulgen reaction, probably because of their protein nature, and results have been obtained comparable with the "developed nucleal stain" of Choudhuri[4]. However, sections treated with hydrolysed deoxyribonucleic acid plus Feulgen reagent and washed exhaustively exhibit an over-all violet coloration, and chromosomes stain by no means selectively, as Danielli[5] has already pointed out. According to my observations, mammalian red cells stain by this procedure most strongly.

Experiments to determine the conditions affecting the intensity of the Feulgen reaction are in progress.

ATUHIRO SIBATANI

Institute for Microbial Diseases,
Osaka University,
Osaka.
May 10.

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Biological Detoxication of 2,4-Dichlorophenoxyacetic Acid in Soils: Isolation of an Effective Organism

IN a recent paper[1], evidence was presented to support the view that the detoxication of the selective herbicide, 2,4-dichlorophenoxyacetic acid in soil was due almost entirely to the action of micro-organisms. The evidence from this and other similar confirmatory work is entirely indirect, and attempts were therefore made to isolate the organism or organisms concerned.

The method employed was to make, on plates of basal medium[2] containing 0·1 per cent of sodium 2,4-dichlorophenoxyacetate, smear inoculations with drops of perfusate from soils enriched in the relevant organisms by the Lees and Quastel perfusion technique[3,4]. The plates were incubated at 25° C. for seven to ten days, when uniform translucent colonies, apparently of a single species of bacterium, appeared with occasional fungal contaminants. Pure cultures of the organisms were established with little difficulty on the same medium and have been subcultured at fortnightly intervals for the last five months. Repeated attempts to subculture the organism on the basal agar medium alone without sodium 2,4-dichlorophenoxyacetate have so far failed, and it seems likely, therefore, that it is using this compound as its sole source of carbon.

That this organism is the one concerned in the breakdown in the soil is supported by inoculation experiments on soil. The garden soil which has so far been used requires from fourteen to twenty-eight days of continuous perfusion with 0·01 per cent sodium 2,4-dichlorophenoxyacetate solution before an enrichment population capable of the maximum rate of breakdown (that is, 0·01 mgm./gm. dry weight soil/hr.) can be established. If, however, the perfusing solution is first inoculated with a suspension of the organism, the maximum rate is rapidly attained, namely, during the first day's perfusion. So far, the organism has resisted all attempts to grow it in liquid culture of the basal medium containing sodium 2,4-dichlorophenoxyacetate alone; but it will grow readily if small traces of agar (0·1 per cent) are added, suggesting the existence of a necessary growth factor in the agar used. Such a growth factor must also be present in the soil. On the other hand, a heavy suspension of the organisms in aerated basal medium will readily break down the sodium 2,4-dichlorophenoxyacetate in the absence of agar.

The bacterium forms large smooth translucent colonies of a dull cream colour, and is a Gram-negative rod of irregular shape and size with Gram-positive granules. Its growth, fermentation reactions, etc., have been tested on the usual differentiating media, and it has thereby been shown to belong to the very common soil organisms of the "*Bacterium globiforme* group" of Lochhead and Taylor[5]. The type organism of the group was originally isolated and described by Conn[6]. The fact that the organism decomposing sodium 2,4-dichlorophenoxyacetate belongs to such a group of very common and prolific soil bacteria opens up a wide field for speculation. The nature of the normal carbon substrate for organisms of the *B. globiforme* group is still largely a matter for conjecture; but the kinetics of breakdown of 2,4-dichlorophenoxyacetic acid in soil, showing a long initial lag phase, suggest that this molecule is not attacked by the normal soil *B. globiforme* flora. The ultimate rapid attack on the molecule is therefore most likely to be accounted for either by the selective proliferation of a mutant endowed with suitable enzyme systems, or by the adaptive development of such enzymes in normal soil species. So far, very few perfusates of enriched soils have been examined in this way, and it is not improbable that other species of organism, also capable of decomposing 2,4-dichlorophenoxyacetic acid, may be isolated in due course. Full details of this work will be published later.

My thanks are due to Dr. W. T. Williams and to Mr. G. S. Spencer for their help in the identification of the organism.

L. J. AUDUS

Botany Department,
Bedford College,
(University of London),
Sussex Lodge, Regent's Park,
London, N.W.1.
June 13.

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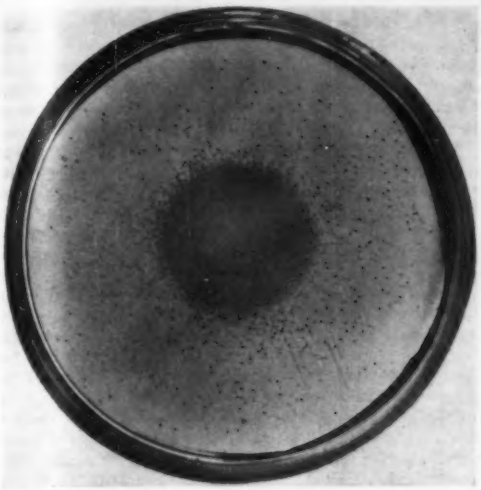
An Antagonist of Dihydrostreptomycin and Streptomycin Produced by *Pseudomonas pyocyanea*

DIFFICULTY arises in testing the sterility of dihydrostreptomycin preparations because there are no antagonists which will inactivate the antibiotic in the test cultures, and so allow any contaminating microbes to grow. The reagents used for inactivating streptomycin in such tests, for example, semicarbazide and hydroxylamine, are inactive against dihydrostreptomycin, because the aldehyde group with which they react has been reduced. Moreover, these reagents, being themselves bacteriostatic, are, in fact, unsatisfactory for testing streptomycin, since some



Growth of *B. subtilis* on plate of nutrient agar containing dihydrostreptomycin, occurring in a zone where the dihydrostreptomycin was antagonized by the previous growth of *Pseudomonas pyocyanea*. Slight inhibition of growth in the centre of the zone is due to antibiotics produced by the *Pseudomonas pyocyanea*

contaminating organisms may fail to develop in the presence of the high concentrations necessary to inactivate concentrated solutions of streptomycin[1]. A search was therefore made for agents active against both streptomycin and dihydrostreptomycin. Soya-bean lipositol, which has been reported to inhibit streptomycin[2], was found to be inactive against both streptomycin and dihydrostreptomycin. Hydrolysis of the glycosidic linkage by the action of an enzyme preparation from snail gut was tried without success. The production of a streptomycinase by *Pseudomonas pyocyanea* was reported by Sureau *et al.*[3]. A culture filtrate of a strain of this bacterium antagonized streptomycin and dihydrostreptomycin. The active principle in the filtrate diffused through 'Cellophane' and was heat stable, and was not, therefore, an enzyme.

A rapid method of demonstrating streptomycin and dihydrostreptomycin inhibitors in bacterial cultures was devised. Nutrient agar plates are prepared containing dihydrostreptomycin in a concentration that will just inhibit growth of the indicator organism added later. Sterile 'Cellophane' disks are laid on the surface of the agar, and the strain under test seeded on to the centre of the 'Cellophane'. After 24 hr. incubation at 37°, the 'Cellophane' and the bacterial colony are removed and the plate then covered with a layer of nutrient agar seeded with indicator organism, for example, *B. subtilis* spores or *Staph. aureus*. The plate is incubated at 37° C. for 24 hr. and the production of antagonists that have diffused through the 'Cellophane' is shown by the presence of colonies of the indicator organism in the upper agar layer (see illustration).

By incorporating both antibiotic and indicator organism in the nutrient agar, the antagonistic power of culture filtrates can be assayed by a cup plate method using a single incubation of 24 hr. The diameter of the zone of growth around the cup is proportional to the logarithm of the concentration of antagonist. When the culture filtrate contains also an antibiotic, for example, pyocyanin, a zone of inhibition is seen inside the zone of growth.

Chromatograms of concentrated extracts of culture filtrates can be developed on filter paper strips using a mixture of butanol and acetic acid. The position of the antagonist on the strips may be shown as a discrete zone by laying the strips on the surface of a large assay tray containing nutrient agar prepared as for assays, and incubating at 37° C.

This appears to be the first instance of an antagonist active against both streptomycin and dihydrostreptomycin, and it is possible that the identification of the factor responsible may lead to a better understanding of the mode of action of these antibiotics. The antagonist is formed during the growth of *Pseudomonas pyocyanea* in a chemically defined, as well as in ordinary, culture medium. It is soluble in fat solvents and stable to acid and alkali. Its activity is markedly affected by the *p*H of the test medium, decreasing with increase in *p*H. Its properties are being examined.

J. W. Lightbown
National Institute for Medical Research,
Mill Hill,
London, N.W.7.
June 12.

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Crystal Structure of $[Cu(en)_2][Hg(SCN)_4]$

Crystals of the compound $[Cu(en)_2][Hg(SCN)_4]$ were kindly supplied by the Chemistry Department of Birkbeck College and an X-ray investigation was carried out to determine its complete crystal structure. The complex $Co[Hg(CNS)_4]$ has already been subject to X-ray investigation[1], showing that as these crystals were tetragonal with space group $I\bar{4}$ there was good evidence that the thiocyanate groups would be tetrahedrally situated about the mercury atom. A study of the copper diethylenediamine complex has revealed that although the sulphurs of the thiocyanates were still tetrahedrally co-ordinated to the mercury atom, the presence of the $Cu(en)_2$ was now sufficient to destroy the tetrahedral arrangement of the remainder of the thiocyanate groups with respect to the mercury atom, thus indicating that there is a flexibility of the —SCN group arising out of a rotation of the group about the Hg—S bond; this flexibility depends on the arrangement of the neighbouring groups. In cases where the surroundings of the $Hg(SCN)_4$ are symmetrically situated about it, as in the $Co[Hg(SCN)_4]$ complex, the thiocyanate groups can take positions compatible with the external symmetry of the crystal. On the other hand, if there is no symmetry around the $Hg(SCN)_4$ complex, this being the case of the $[Cu(en)_2][Hg(SCN)_4]$, the thiocyanates take up unsymmetrical positions satisfying the structural features of geometrical packing and charge neutralization. This may explain why these crystals occur in a system of lower symmetry.

The crystals, of a deep purple colour, are monoclinic, well-developed prismatic plates with {010} dominating. The optics give a positive sign with γ parallel to the *b*-axis and β lying at about 24° to the *c*-axis in the obtuse angle. Dichroism is observed on {010}.

The cell dimensions are: $a = 7{\cdot}51$ A., $b = 18{\cdot}03$ A., $c = 14{\cdot}20$ A., $\beta = 96° 32'$. The space group is $P2_1/c$

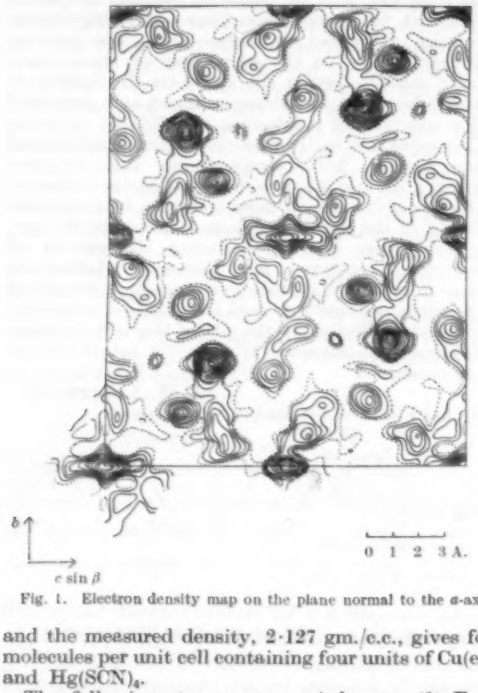

Fig. 1. Electron density map on the plane normal to the *a*-axis

and the measured density, 2·127 gm./c.c., gives four molecules per unit cell containing four units of $Cu(en)_2$ and $Hg(SCN)_4$.

The following steps were carried out. (1) From Patterson analysis on the three main projections the co-ordinates of the mercury and copper atoms were obtained. The mercury atoms lie in general positions, while the copper atoms are found at the centres of symmetry $\frac{1}{2}00$, $\frac{111}{222}$; $\frac{1}{2}0\frac{1}{2}$, $\frac{11}{22}0$. (2) Using the phase contribution of these heavy atoms for all three projections, it was possible to locate the sulphur atoms. (3) The positions of the lighter (carbon and nitrogen) atoms of both the thiocyanate and ethylenediamine groups had to be obtained from three-dimensional Fourier synthesis using the phase contributions of the mercury, copper and the four sulphur atoms.

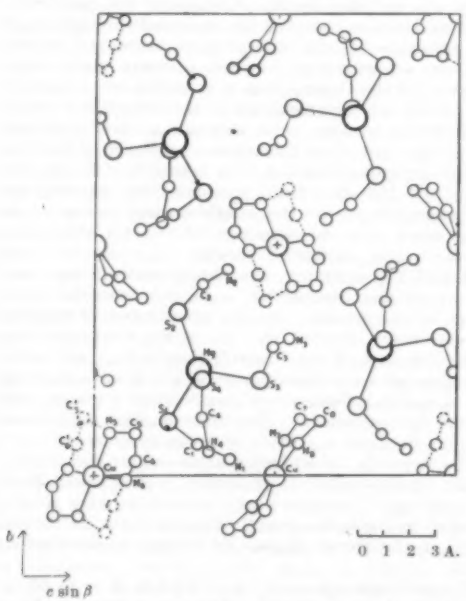

Fig. 2. Atomic arrangement corresponding to Fig. 1

From Fourier sections parallel to the three axes, it was possible to confirm that: (*a*) the four sulphur atoms are tetrahedrally arranged about the mercury atom at a mean distance of 2·56 A. and with a mean S—Hg—S angle of 109° 16′; (*b*) the thiocyanate groups appear to be kinked; this was confirmed independently for individual groups. It should be pointed out that the analysis is incapable of deciding unequivocally whether the group is S—C—N or S—N—C; but for the moment chemical evidence suggests that it is probably S—C—N, and this had been tentatively accepted. The S—C—N angle has a mean value of 156° 24′ and the mean S—C and C—N distances were found to be 1·57 A. and 1·33 A. respectively. (*c*) The amino-nitrogens of the ethylenediamine groups are bonded to the copper atoms forming five-membered rings. It is found that the Cu(en)$_2$ rings are non-planar, and there is also strong evidence of two possible stereochemical configurations for these ring systems which is being investigated at the moment.

It was, in addition, found that two nitrogens of the thiocyanate groups are co-ordinated to the copper atoms, thus giving it a six-fold co-ordination. Fig. 1 is a Fourier projection of the electron density on a plane normal to the *a*-axis based on the phase contribution of $Hg(SCN)_4$ and Cu. The atomic positions marked on Fig. 2 are those obtained from the sections.

A detailed description of the work will appear elsewhere.

One of us (H. S.) is indebted to the British Council for a maintenance grant which enabled her to undertake this work.

HELEN SCOULOUDI
C. H. CARLISLE
Birkbeck College Research Laboratory,
21 Torrington Square,
London, W.C.1.
April 28.

[1] Jeffery, J. W., *Nature*, **159**, 610 (1947).

The Reactions Leading to the Sodium *D*-Line Radiation in Flames

IN a recent communication[1] by one of us, substantial evidence was given of the suppression of the *D*-line sodium radiation in hydrogen flames by additives—such as carbon dioxide and other polyatomic molecules—which likewise inhibit the chemiluminescence of manganese-promoted calcium oxide in contact with the flames. It was considered that the effect of the additive was greatly to reduce the concentration of hydrogen atoms, the presence of which is necessary for the chemiluminescent effect referred to.

The suppression of the *D*-line does not arise from the inability of sodium salts to vaporize when the additives are present. This can readily be shown by bringing near the colourless flame a second flame in which hydrogen is burning at a carefully cleaned quartz tip. At the meeting point of the two flames an intense *D*-line is given, indicating that abundant molecules of sodium salts are available in the former.

Since the measurement of flame temperatures by the *D*-line reversal method generally gives quite

reasonable results[2,3] (so long as the gas through which the incident radiation passes is at fairly uniform temperature) the excitation is unlikely to be a chemiluminescent effect in these cases. Since it is equally unlikely that hydrogen atoms assist in the quenching of excited sodium, we consider that the part played by the hydrogen atoms is to cause the formation of free sodium atoms from its salt according to the equation

$$NaX + H \rightarrow HX + Na.$$

If X is halogen, this reaction is nearly thermally neutral, the heat evolved being 4·4 k.cal. for the chloride, − 5·3 k.cal. for the bromide, and − 8·3 k.cal. for the iodide. In contrast, the dissociation reactions of the type $NaX \rightarrow Na + X$ are strongly endothermic, the dissociation energy being greatest in the case of the chloride (97·7 k.cal.) and smallest in that of the iodide (71·7 k.cal.[4]).

Since the line-reversal method for measuring gas temperatures is essentially a null method, it will be clear that the explanation given fully accords with the facts, namely, that the intensity of the line is a function of the hydrogen-atom concentration (and the nature of the sodium salt) and the reversal point a function of the ambient temperature.

J. R. Arthur
D. H. Bangham
R. H. Baulk
G. Whittingham

British Coal Utilisation Research Association,
Leatherhead, Surrey.
June 5.

[1] Arthur, J. R., *Nature*, **165**, 557 (1950).
[2] Kohn, H., *Ann. Physik.*, **44**, 749 (1914).
[3] Lewis, B., and Von Elbe, G., "Combustion Flames and Explosions of Gases", 329 (Cambridge, 1938).
[4] Gaydon, A. G., "Dissociation Energies and Spectra of Diatomic Molecules" (London, 1947).

The Meyer Law for Hardness Tests

The indentation test, made by forcing an undeformable ball into the test piece, of which the Brinell test is the most extended form, is governed by an empirical relation between load and diameter, $P = a\,d^n$, due to Meyer.

The constants a and n are frequently employed for estimating strain-hardening, since a increases, while n decreases with work-hardening. The law can be checked and a new meaning can be given to these constants, starting from classical laws of elasticity.

According to Hertz[1], the depth of the indentation or its diameter is given by

$$h = \frac{9}{64}\left(\frac{1-\nu}{G}\right)^2 \frac{P^2}{R}$$

$$d^3 = 3\left(\frac{1-\nu}{G}\right) P.R,$$

where G is the modulus of rigidity and ν the reciprocal of Poisson's ratio. If Young's modulus is used, the second equation becomes:

$$d^3 = \frac{3(1-\nu^2)}{E} P.D, \qquad (1)$$

where D is the ball diameter. Therefore, in the elastic range, Meyer hardness number is easily seen to be

$$H_M = \frac{4P}{\pi d^2} = \frac{4E}{3\pi(1-\nu^2)} \frac{d}{D}. \qquad (2)$$

Poeschl[2] suggested that this equation could be employed in the plastic range, maintaining the formal similarity, but replacing the constant E by an empirical value obtained experimentally, in the plastic range, by an indentation test. Replacing Young's modulus E by an instantaneous plastic modulus π, we have found that its rate of variation with increasing strain is of the form:

$$\pi = E\left(\frac{d_0}{d}\right)^\eta, \qquad (3)$$

so that π represents the above-mentioned modulus of plasticity and d_0 and η are constants. The equation has been tested within the range of values $0{\cdot}1 < d/D < 0{\cdot}7$, and it has been proved correct whatever the ball diameter. Going beyond lower values $d/D = 0{\cdot}1$, the modulus π should increase, approaching E. This assumption enables us to establish an indentation elastic point, the impression diameter of which would be d_0.

Substituting (3) in $P = \frac{\pi}{3(1-\nu^2)} \frac{d^3}{D}$ gives

$$P = \frac{E.d_0^\eta}{3(1-\nu^2)D}.\, d^{3-\eta}; \qquad (4)$$

therefore, the constants of the Meyer Law are

$$a = \frac{E.d_0^\eta}{3(1-\nu^2)D} \quad \text{and} \quad n = 3 - \eta.$$

By adopting, provisionally, values for E determined in homogeneous compression tests, taking $\nu = 0{\cdot}3$ and extending logarithmic diagrams, $\log \pi = f[\log d/D]$, down to $\pi = E$, and reading, then, the value of d_0/D, it is possible to compute a and n. From the accompanying table, it can be seen that the calculated values are consistent with the experimental ones. From (4) an elastic hardness relationship could also be found:

Material	$E.10^{-6}$	Mean values from 2-, 5-, 5- and 10-mm. diameter balls		Calculated values (eq. 3)		Elastic limit	
		n	$a.D^{n-2}$	n	$a.D^{n-2}$	H_0 (kgm./mm.²)	Hertzian hardness p_m
Copper	12·7	2·31	52	2·31	50·8	8·45	3·17
70/30-Brass	9·15	2·27	59·9	2·24	61·1	16	6·45
Aluminium (commercial)	7·1	2·33	61	2·31	66·1	13·8	5·2
Soft steel	21	2·36	159	2·37	157	22·3	8·4

$$H_0 = \frac{4E}{3\pi(1-\nu^2)} \frac{d_0}{D}.$$

H_0 is the "mean pressure strainless indentation hardness", which represents simply an extrapolation of the Meyer Law. The Hertzian hardness, that is, the maximal pressure on the middle of the impression, is given by:

$$p_m = \frac{E}{2\pi(1-\nu^2)} \frac{d_0}{D}. \qquad (5)$$

Emilio Jimeno
Jose Terraza

Metallographic Laboratory,
University of Madrid.
March 20.

[1] Lorenz, "Technische Elastizitaetslehre" (Munich, 1913).
[2] Poeschl, *Archiv. Eisenhütt.*, **16**, 425 (1934).

FORTHCOMING EVENTS

Wednesday, August 30—Wednesday, September 6

British Association for the Advancement of Science (at Birmingham).—Annual Meeting.

Wednesday, August 30

(in the Town Hall), at 8.30 p.m.—Sir Harold Hartley, F.R.S.: "Man's Use of Energy" (Presidential Address).

Friday, September 1

(in the Great Hall of the University, Edgbaston), at 8 p.m.—Prof. K. von Frisch: "The Language of Bees".

Sunday, September 3

(in the Great Hall of the University, Edgbaston), at 8 p.m.—Dr. E. W. Barnes, F.R.S., Bishop of Birmingham: "Science, Religion and Moral Judgments".

Monday, September 4

(in the Great Hall of the University, Edgbaston), at 8 p.m.—Dr. A. C. B. Lovell: "The New Science of Radio Astronomy."

Wednesday, August 30—Wednesday, September 6

(in the Department of Mechanical Engineering, The University, Edgbaston), at 10.30 a.m. to 8 p.m.—Exhibition on "Energy in the Service of Man".

Friday, September 1

INSTITUTION OF ELECTRICAL ENGINEERS, London Students' Section (at Savoy Place, Victoria Embankment, London, W.C.2), at 7 p.m.—Sir Arthur Fleming: "Recent Developments in Engineering."

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on or before the dates mentioned:

ASSISTANT IN THE DEPARTMENT OF CHEMISTRY (to teach Inorganic Chemistry to H.N.C. standard and Analytical Chemistry in the full-time Laboratory Assistants' course), at the Widnes Municipal Technical College—W. R. Wainwright, Education Office, Lugsdale Road, Widnes (September 2).

LECTURER IN CHEMISTRY—The Principal, Acton Technical College, High Street, Acton, London, W.3 (September 2).

MECHANICAL and AERO ENGINEERS and PHYSICISTS (Experimental Officer grade, unestablished) at the National Gas Turbine Establishment—The Ministry of Labour and National Service, Technical and Scientific Register (K), York House, Kingsway, London, W.C.2, quoting C.427/50A (September 2).

OFFICER (with an honours degree in physics, though a general honours degree in physics and mathematics or physics and chemistry would be considered) for scientific work on woollen processing in mills, and in the laboratories—The Secretary, Wool Industries Research Association, Torridon, Headingley, Leeds 6 (September 2).

INDEXER (with good general knowledge and a degree in science) at the Food Investigation headquarters (Department of Scientific and Industrial Research), Cambridge—The Ministry of Labour and National Service, Technical and Scientific Register (K), York House, Kingsway, London, W.C.2, quoting F.489/50A (September 4).

INSPECTOR under the Dangerous Drugs Acts in the Home Office—The Secretary, Civil Service Commission, 6 Burlington Gardens, London, W.1, quoting No. 3231 (September 7).

PRINCIPAL SCIENTIFIC OFFICER at the Atomic Energy Research Establishment, Harwell, to take charge of a small group engaged in problems of heat transfer, and special problems arising in the development of nuclear energy for power purposes, etc.—The Secretary, Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. 3235 (September 7).

LECTURER (Grade II) IN PHARMACOLOGY—The Registrar and Secretary, The University, Bristol (September 14).

PUBLIC RELATIONS OFFICER at the Long Ashton Research Station, Bristol—The Registrar and Secretary, The University, Bristol (September 16).

LECTURER or an ASSISTANT LECTURER IN CHEMICAL ENGINEERING—The Registrar, College of Technology, Manchester 1 (September 25).

PHYSICAL CHEMIST to act as deputy head of the Chemistry Laboratories (Ref. TT/237), an experienced RESEARCH PHYSICIST to act as deputy head of the Physics Laboratories and to work on the physical properties of coal (Ref. TT/238), CHEMISTS (physical and organic) with experience in metallurgy, distillation, colloid chemistry, surface chemistry or coal tar chemistry (Ref. TT/239), and experienced RESEARCH PHYSICISTS (Ref. TT/240), at the Central Research Establishment at Stoke Orchard, near Cheltenham—The National Coal Board, Establishments (Personnel), Hobart House, Grosvenor Place, London, S.W.1, quoting the appropriate Ref. No. (September 25).

CHEMISTS I (6), and CHEMISTS II (12) in the Ministry of Supply—The Secretary, Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. 3227 (September 28).

ASSISTANT DIRECTOR OF THE COMMONWEALTH BUREAU OF DAIRY SCIENCE, at the National Institute for Research in Dairying, Shinfield, Reading—The Secretary, Commonwealth Agricultural Bureaux, 2 Queen Anne's Gate Buildings, London, S.W.1 (October 1).

LECTURER IN GEOLOGY (to specialize in Petrology and Mineralogy), at the New England University College (University of Sydney), Armidale, N.S.W.—The Secretary, Association of Universities of the British Commonwealth, 5 Gordon Square, London, W.C.1 (October 1).

KEEPER OF THE QUEEN VICTORIA MUSEUM, Salisbury, Southern Rhodesia—The Director, National Museums of Southern Rhodesia, c/o High Commissioner, Rhodesia House, Strand, London, W.C.2 (December 1).

PROFESSIONAL ENGINEERS in many Departments of the Civil Service—The Secretary, Civil Service Commission, Trinidad House, Old Burlington Street, London, W.1, quoting No. 3225 (December 31).

ASSISTANT BIOCHEMIST IN THE DEPARTMENT OF PATHOLOGY—The Secretary, Royal Infirmary, Bolton.

ASSISTANT PROFESSOR or ASSOCIATE PROFESSOR IN THE DEPARTMENT OF PHYSICS—G. M. Shrum, Head of the Department of Physics, University of British Columbia, Vancouver, B.C., Canada.

ASSISTANT STATISTICIAN (for work mainly concerned with the analysis of foot dimensions, but will include the statistical treatment of physical and chemical laboratory data)—The Director, British Boot, Shoe and Allied Trades Research Association, Satra House, Rockingham Road, Kettering, Northants.

ENTOMOLOGIST'S ASSISTANT (male or female) IN THE AGRICULTURAL DEPARTMENT, Government of Tanganyika—The Crown Agents for the Colonies, 4 Millbank, London, S.W.1, quoting M/N/23491/3A.

GROUP MANAGER of the Ministry of Supply's Capenhurst Factory, Chester, to be responsible for the management of a large chemical engineering plant operating under high vacuum—The Ministry of Supply, Division of Atomic Energy (Production), Risley, Warrington, Lancs.

HEAD OF THE DIVISION OF PLANT PATHOLOGY—The Director, Tea Research Institute of Ceylon, Talawakelle, Ceylon.

LECTURER IN THE PHYSICS DEPARTMENT—The Principal, Northampton Polytechnic, St. John Street, London, E.C.1.

PHYSICAL CHEMIST or PHYSICIST in the Chemical Division, to assist fundamental work on dyes and their solutions—The Director of Research, British Cotton Industry Research Association, Shirley Institute, Didsbury, Manchester 20.

PROFESSOR OF CHEMISTRY, and a LECTURER IN BOTANY, at the College of Arts and Science, Baghdad—The Cultural Attaché, Iraqi Embassy, 22 Queen's Gate, London, S.W.7.

SCIENCE GRADUATE (man or woman) for abstracting technical literature, etc.—The Secretary, Research Association of British Rubber Manufacturers, 105 Lansdowne Road, Croydon.

SCIENTIFIC ASSISTANT, for information service and abstracting journal—The Director, Commonwealth Bureau of Dairy Science, Shinfield, Reading, Berks.

REPORTS and other PUBLICATIONS

(not included in the monthly Books Supplement)

Great Britain and Ireland

Science Museum. Hand List of Short Titles of Current Periodicals in the Science Library. Sixth edition. Pp. iv+282. (London: H.M. Stationery Office, 1950.) 7s. 6d. net. [47

Wool Industries Research Association. Report of the Proceedings at the Thirty-first Annual General Meeting. Pp. 8. (Leeds: Wool Industries Research Association, 1950.) [47

Philosophical Transactions of the Royal Society of London, Series B: Biological Sciences. No. 613, Vol. 234: The Effects of Entero-Posterior Reversal of Lengths of the Primitive Streak in the Chick. By M. Abercrombie. Pp. 317–338. 9s. No. 614, Vol. 234: Structure and Development of the Reproductive System of some Species of Nematocera (Order Diptera: Suborder Nematocera.) By S. E. Abul-Nasr. Pp. 339–396. 13s. (London: Cambridge University Press, 1950.) [47

British Welding Research Association. Annual Report, 1949–50. Pp. 50. (London: British Welding Research Association, 1950.) [57

Ministry of Health. Publicity for Local Government; Final Report. Pp. 17. (London: H.M. Stationery Office, 1950.) 6d. net. [57

Ministry of Fuel and Power. Reports of H.M. Inspectors of Mines for the Year 1949. East Midland Division. Report by W. B. Brown. Pp. ii+24+5 plates. (London: H.M. Stationery Office, 1950.) 1s. 3d. net. [57

This is the British Glass Industry. Pp. 52. (London: Glass Manufacturers' Association, 1950.) 5s. [57

Other Countries

Snellius Expedition in the Eastern Part of the East Indian Archipelago, 1929–1930. Vol. 2: Oceanographic Results, Part 6, Tables; Serial and Bottom Observations, Temperature, Salinity and Density. By P. M. Van Riel, H. C. Hamaker and L. Van Eyck. Pp. v+44. (Leiden: E. J. Brill, 1950.) [57

Colony and Protectorate of Kenya. Catalogue of Kenya Timbers. By S. H. Wimbush. Pp. 69. (Nairobi: Government Printer, 1950.) 2s. 6d. [57

Research and its Organization. By Dr. Ellice McDonald. Pp. 96. (Newark, Del.: Biochemical Research Foundation, 1950.) [57

Institut Royale des Sciences naturelles de Belgique. Mémoires, Deuxième Série, Fasc. 33: Résultats scientifiques des croisières du Navire-École Belge *Mercator*, Vol. 4, Téléostéens disymétriques (Heterosomata), par Paul Chabanaud; Méduses, par Gilbert Ranson; Holothuries, par Gustave Cherbonnier; Poissons, par Max Poll. Pp. 269. Mémoires, Deuxième Série, Fasc. 34: Recherches sur la forme et la mécanique de développement des coquilles des Lamellibranches. Par Lucien Lison. Pp. 87. Mémoires, Deuxième Série, Fasc. 35: Contribution à l'étude de la croisance pubertaire de l'homme. Par Dr. François Twiesselmann. Pp. 88. Mémoires, Deuxième Série, Fasc. 36: The African Dorilaidae (Pipunculidae: Diptera.) By D. Elmo Hardy. Pp. 80+6 plates. (Bruxelles: Institut Royale des Sciences naturelles de Belgique, 1949.) [67

Erdöl und Tektonik in Nordwestdeutschland. Sammelband enthaltend die Vorträgen der Erdöltagung in Hannover vom 9 bis 11 September 1947. Unter Mitwirkung zahlreicher Fachgenossen herausgegeben von A. Bentz. Pp. 387+15 plates. (Celle: Amt für Bodenforschung, 1950.) [67

Geologisches Jahrbuch für die Jahre 1943–1948. Herausgegeben von den Geologischen Landesanstalten der Bundesrepublik Deutschland. Band 64. Pp. xxxvi+646+6 plates. (Celle: Amt für Bodenforschung, 1950.) [67